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ESSAYS
ON
SEVERAL PARTS
OF THE
Animal Oeconomy.

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By JAMES KEILL, M. D.

Profecto veriſimile eſt, & Hippocratem & Eraſiſtratum, *& quicunque alii, non contenti Febres & Ulcera agitare, rerum quoque naturam ex aliqua parte ſcrutati ſunt, non ideo quidem Medicos fuiſſe, verum ideo quoque Majores Medicos exſtitiſſe*. Celſ. *in* Præf.

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ERRATA.

PAge xiii. line 17. for *none* read *one*. p. 2. l. 10. for *be* read *he*. p. 36. l. 16. for —*b* read b^2. p. 20. l. 5. read *that the Body*. p. 74. l. 9. for $\frac{s^2c}{4r^2}$ read $\frac{sc}{2r}$. in the ſame Line for $::\frac{s^2c}{4r^2}$ read $::\frac{sc}{2r}$. and again for $:\frac{s^2c}{4r^2}$ read $:\frac{s^2c}{2r^2}$ p. 75. l. 2. for $\times$ 100 read + 100. p. 119. l. 14. for 0.616. read 0.0616. l. 16. the ſame again. p. 120. l. 9. for 5. read 0.5. p. 138. l. 16. for 3.4. read 34. p. 139. for 2401. read 3401. p. 223. l. 16. for *Secretion* r. *Section*.

THE PREFACE.

Diſeaſes being purely Diſorders of the Animal Oeconomy, whatſoever can add any new Light to our Knowledge of this, muſt neceſſarily clear the Nature of thoſe, eſtabliſh the Practice of Phyſick upon a ſurer Foundation, and enable Phyſicians to make truer and more certain Judgments in moſt Caſes.

The Animal Body is now known to be a pure Machine, and many of *its Actions and Motions are demonſtrated to be the neceſſary Conſequences of its Structure. The manner of Viſion is ſhewn in Opticks.* Borelli *has given us the Mechaniſm of the Bones and Muſcles for the moving of the Joints. And ſince the Diſcovery of the Circulation of the Blood by the famous Dr.* Harvey, *many uſeful Propoſitions concerning its Motion and Velocity have been determined by* Bellini. *Dr.* Pitcairne *has explained the mechanical Structure of the Lungs; ſhewn us the reaſon of the different Paſſages of the Blood, thro' the Heart of the Fœtus; the neceſſity of breathing after Birth; and how the ante-natalitial Ducts are ſtopp'd by breathing: He has likewiſe demonſtratively explain'd the Symptomes of the Diſeaſes of the Eyes, and demonſtrated the circular Figure of the Orifices of the Glands. Dr.* Friend *has wrote in a mechanical* *way upon the Menſes; Dr.* Cheyne *upon Fevers; and Dr.* Mead *of Poiſons; and all of them have handled theſe Subjects more rationally than ever any did before them. In the following Sheets is contained a Calculation of the Force of the Air upon the Blood in Breathing, of the Quantity of Blood in the Human Body, of its abſolute Velocity in the* Aorta. *The uſe of the Spleen and* Vena Porta *is now no longer a* Myſtery; *and many* Phænomena *of the Animal Body which the Ages paſt thought inexplicable, have now by ſeveral been made the Subjects of Geometrical Demonſtration. That many Things ſtill remain undiſcovered, is not, that of their own Nature they are leſs capable of Demonſtration; but that the* Data *are not ſufficient, we are not yet fully appriſed of all the Circumſtances, which conduce to produce ſuch* Phænomena. *If ſome things* *which to former Ages have appeared unaccountable, are now as clear and demonſtrable as the Preſſure of the Air, why ſhould we not hope for a Diſcovery of the Things that are ſtill hid from us? If we endeavour after them, there is all the reaſon in the World to believe we ſhall have Succeſs, if we conſider the Progreſs that has already been made, notwithſtanding the mechanical Philoſophy as applied to Phyſick is ſtill in its Infancy.*

Now ſince the Animal Body is a pure Machine, and all its Actions from which Life and Health do flow are the neceſſary Conſequences of its Oeconomy; muſt not all the Symptomes of Diſeaſes be likewiſe the neceſſary Conſequences of the Alteration of this Oeconomy? And do they not as neceſſarily flow from this Change, as the Actions by which Life and Health are continued, did flow from the Oeco-

nomy before the Change. If a Pendulum of ſuch a length makes a Clock to go exactly true; does not the Alteration of the Pendulum as neceſſarily cauſe it to go too faſt or too ſlow? and when all the reſt of the Movement is known to be in good order, does not the quick or ſlow Motion of the Clock, as neceſſarily ſhew the Fault of the Pendulum? It is the ſame thing in the Animal Body, for the ſame reaſoning holds good in all ſort of Machines, whoſe Motions are the neceſſary Conſequences of their Structures: nor is the Caſe in the leaſt altered, that we have a Principle within us, not ſubject to the Laws of Motion; for our Souls are not at all conſcious of the inward Motions of the Body upon which Life and Health depend; and tho' it do's ſometimes influence our Health, yet the Irregularities it produces in the Oeconomy are to be rectified the ſame *way as if they had proceeded from other Cauſes. Therefore it demonſtratively follows, that the greater our Knowledge of the Animal Oeconomy is, the better the Nature of Diſeaſes muſt be known.*

It muſt indeed be confeſſed that this Method of improving the Art of Phyſick is full of Difficulty, but the Nature of things cannot be altered; if it is to be improved, it muſt be by a Knowledge in the Animal Oeconomy, there being no other Method but what does really and in effect depend upon that.

Some do pretend that the Art of curing Diſeaſes, is only to be promoted by Experiments, by obſerving what Things are hurtful, what beneficial in Diſeaſes, that the Study of Nature and the Knowledge of the Body is altogether ſuperfluous, and of as little uſe, as it would be to a Sailor to know the Reaſon of the Tides, or *how to explain the Phænomena of the Loadſtone. But if we conſider the Number of Diſeaſes, their different Species, different Appearances according to the almoſt infinite Variety of the Conſtitutions of our Bodies, and the Air in which we live. If we reflect likewiſe on their various Complications, on the infinite variety of Medicines, and the critical Times of uſing ſometimes one, and ſometimes another, we may as well expect that a blind Man ſhould ſhoot flying, or one that is deaf tune an Organ, as that any one without the Knowledge of the Animal Oeconomy ſhould ever find out a Remedy for any one Diſtemper. The Art of curing did indeed at firſt riſe from Experiments, and it cannot be denyed that ſeveral good Remedies have been found out by chance, or rather by Divine appointment, as without doubt the Uſe of the Bark was by the Indians; whom* *we may reaſonably ſuppoſe to have been ignorant of the Animal Oeconomy; but no Man can think this a good Method for improving of any Science: If indeed Experiments are directed, by a Knowledge in the Animal Oeconomy, ſomething may be hoped for from ſuch a Method; and the greater the Skill is by which the Experiments are directed, the greater will be the Probability of Succeſs; becauſe by that we can aim more directly and certainly at the Irregularities of the Oeconomy; and he that knows the Diſeaſe is more likely to cure than he that is wandring and dubious in his Mind, and uncertain what it is he ought to aim at. If he hits the Mark it is owing more to mere chance, than any good Skill. Experiments are the only Foundation upon which by a juſt reaſoning we come at the Knowledge of any Phænomenon of Nature. Thus only Ana-*

Anatomical Experiments, and Obſervations upon the Structure of the Parts, Nature of the Blood, and Secretions, can enable us to underſtand the Phænomena of the Animal Body; without them the raiſing of Theories and Hypotheſes is but building of Caſtles in the Air. The Theory indeed of any Art, which has already arrived at its higheſt Perfection, and which has all its Circumſtances known, may perhaps be of as little uſe, as that of the Tides and Loadſtone would be for ſailing in the Channel: But either of theſe might be of great uſe to a Sailor taken out of his Knowledge to an unknown Part of the World. Phyſick has not as yet arrived at its greateſt Perfection in the curing of any one Diſeaſe; we are ſtill ignorant of more than we know, and the Circumſtances of Diſeaſes are infinitely various, and no general Rules whatſoever can be applied to parti-

particular Caſes, without the Knowledge of the reaſon of the Rule, that is, without underſtanding the Animal Oeconomy, upon which all Rules of Phyſick are built.

But the Method of curing Diſeaſes, by drawing Indications from the evident and conjunct Cauſes, has been always moſt approved by the beſt and Generality of Phyſicians. The Knowledge of theſe Cauſes is not to be attained by reaſon, but by a cloſe and aſſiduous Obſervation of all the Appearances in the ſeveral Stages of a Diſtemper. The firſt that excelled in this Knowledge was the Divine Hippocrates, *whoſe Delineations of Diſeaſes are truly charming. In them one may diſcern a wonderful Attention to all even the minuteſt Operations of Nature, which produced a ſurprizing Sagacity in judging of future Events. In this Method ſeveral of the Ancients have follow-*

followed him, but none ever came ſo near to him, as the deſervedly renowned Dr. Sydenham, *and Dr.* Morton, *whoſe Hiſtories of Diſeaſes, for a full, exact and nice Enumeration, and Deſcription of evident Cauſes, Signes and Symptomes, for a judicious diſtinguiſhing of the ſeveral Species of the ſame Diſeaſes, and for juſt Prognoſticks founded upon a careful Obſervation of the common Effects of ſuch and ſuch Appearances, have ſurpaſſed all Hiſtories of the Modern Phyſicians.*

This is the Knowledge which, added to that of the Animal Oeconomy, can only make a Phyſician; none skilled in Geometry may as well pretend to be a good Aſtronomer, without knowing the Motions and Revolutions of the Heavenly Bodies, as a Philoſopher, or one skilled in the Animal Oeconomy, to be a Phyſician without the exact Knowledge of the

Hiſtories of Diſeaſes. And as one ignorant of Geometry can make but a wretched Aſtronomer, ſo he can make no better a Phyſician that has not laid a good Foundation of the Animal Oeconomy. If we conſider the Animal Body as a Machine, its Diſeaſes, and all their Symptomes are only the irregular Motions of the Machine. Now ſuppoſe a Man ignorant of the Structure of a Clock or Watch, it is impoſſible he ſhould ever be able to put it in right Order, tho' he had never ſo exact an Hiſtory of its irregular Motions. So a Phyſician ignorant of the Animal Oeconomy, is ignorant of the Structure of the Machine he undertakes to regulate, and the beſt and exacteſt Hiſtories of Diſeaſes can never ſuggeſt to him any Indication of Cure. It is therefore the Animal Oeconomy which alone can enable us by reaſoning upon the Cauſes, Signes and Symptomes *of Diſeaſes, to find out their Natures, and to deduce true and juſt Indications of Cure.*

If we examine the Method of curing any Diſtemper we ſhall find what I have ſaid to be true. For inſtance, do not all the Symptomes of the Jaundice ſhew us that the Liver is obſtructed? And do we not deduce this Obſtruction by our Knowledge of the Animal Oeconomy? And does not this Obſtruction indicate Bleeding, Vomiting, Purging and Deobſtruent Medicines, which are uſed in curing of this Diſeaſe? If we know the Nature of the Humour which cauſes the Obſtruction, perhaps Remedies might be found to cure ſuch Jaundice as are now found to be incurable: For different Subſtances require different Reſolvents, as every one that is acquainted in Pharmacy and Chymiſtry knows. From the Symptomes of the Jaundice we juſtly draw the

the Indication for giving deobſtruent Medicines, but what are the moſt proper Medicines of this kind, we know not; becauſe we are ignorant of the Nature of the Obſtruction. Our Indications therefore are true and juſt, ſo far as our Knowledge of the Animal Oeconomy reaches; but where that leaves us we only grope in the dark, and find out Remedies by Chance.

But this will be ſtill more evident if we conſider, there is no Diſeaſe, better known, or which has its moſt minute Circumſtances better deſcribed than a Tertian Fever; yet becauſe we are ignorant of the Nature of the Blood, which is the Seat of this Diſeaſe, its Hiſtory does not help us to any Indication, which if anſwered will work a Cure, but we are obliged to the ignorant Indians for our knowledge in curing this Diſeaſe. And here again to ſhew the Neceſſity of the

the Knowledge of the Animal Oeconomy, and how vain a thing Empiriciſm is, tho' a more noble Specifick than the Bark was never known; yet we are frequently forc'd, when Intermitting Fevers are complicated to call in to our Aſſiſtance the Knowledge of the Animal Oeconomy; and by Vomiting, Purging and other proper means, to render that Specifick uſeful, which before was of no effect.

If the Animal Oeconomy were perfectly underſtood, and the Hiſtories of Diſeaſes exactly known, the right Method of Curing each Diſeaſe might be evidently and certainly deduced; and therefore when the Hiſtory of a Diſeaſe is exactly known, if the right Method of curing it cannot be deduced, it muſt be becauſe the Animal Oeconomy is not underſtood; and from hence it follows that our Skill in curing of Diſeaſes whoſe Hiſtories are *exactly known, (abſtracting what we are obliged to Empiricks for) is always proportional to our Knowledge of the Animal Oeconomy.*

The Animal Oeconomy is its ſelf a conſiderable Part of natural Philoſophy, and our Bodies are ſtrongly influenced by Variety of Diets, and ſo many things from without, that indeed the whole ſtudy of Nature ſeems to be uſeful to him that would underſtand it. And every diſcovery in things that affect us, ſeems to be an Improvement of Phyſick. Some of the Ancients have indeed left us very judicious and accurate Hiſtories of Diſeaſes; but ſince the diſcovery of the Circulation of the Blood, and the late Improvement of natural Philoſophy; our Reaſonings upon theſe Hiſtories, in order to find out the Seat and Nature of the Diſtemper and from them to deduce a right Method of curing, and the whole Practice of *of Phyſick by the Invention of many uſeful Remedies, is ſo much refined, that whoever ſhould affirm the contrary, would ſeem to me neither to have read the Ancients nor to be acquainted with the Practice of the Moderns.*

But notwithſtanding the great Advantages Phyſick has received from natural Philoſophy; it muſt be owned, that it has likewiſe received a very great detriment from the too common Method of philoſophizing; that is by laying down of Principles not drawn from the Phænomena *of Nature, but uncertain Fictions of the Brain; ſuch as are the firſt and ſecond Elements of the* Carteſians, *which are purely Chimerical, and have no Foundation in Nature; and yet their whole natural Philoſophy depends upon them: Tho' their reaſoning upon ſuch fictitious Principles were juſt, yet no* Phænomenon *of Nature* *demonſtrating their Exiſtence, the beſt that cou'd be ſaid of their Philoſophy is, that for ought we know, it is meerly poſſible; but that Nature does actually work this way, can never be ſhewn, till the truth of their Principles can be demonſtrated. Moſt Theories of Diſeaſes are built upon ſuch Principles, and therefore we never can have any Certainty, or indeed ſo much as a Degree of Probability, that the Indications drawn from them are right, or ſuch as if anſwered, would cure the Diſeaſe. If a Man may ſuppoſe any Principles which are not evidently falſe, he may at the too common looſe way of reaſoning, give a thouſand Solutions of the Nature of every Diſtemper, all equally true, and all indicating different Methods of curing. Tho' ſuch a Knowledge may ſatisfie the Curioſity of a Philoſopher, yet it can be no ſufficient ground for eſtabliſhing*

ing the Practice of Phyſick upon: For a Man to hazard his Life (and he ought to be more cautious of another's) upon the truth of an Hypotheſis which is barely poſſible, is to run a greater Riſque than he does, who ventures his Eſtate in a Lottery, where it is only poſſible, but not at all probable that he ſhould be a Saver.

But this ſort of Philoſophy is not only uſeleſs, but it is alſo prejudicial to Phyſick; for Men being generally fond of the Productions of their own Brains have ſtudied theſe more than they have done the Operations of Nature in the ſeveral Periods of Diſeaſes, and have not ſtuck to mould and frame Diſeaſes to anſwer their Hypotheſes; ſo that moſt of the late Hiſtories of Diſeaſes, are only Philoſophical Romances, and contain nothing of that diligent Obſervation of Nature which gained Hippocrates *immortal*

immortal Honour, and without which it is impoſſible that ever the Art of Phyſick ſhould be improved.

But ſuch is the Narrowneſs of the Humane Intellect, that few Men are fitted for various Studies, or even for the ſeveral Parts of the ſame Science. Many have been very nice and exact in making Aſtronomical Obſervations, that have had but a very moderate Skill in Geometry, and ſuch as have excelled in this have been deficient in that. And Men either from a want of Integrity and a Senſe of that Truth and Juſtice that is due to Mankind, or from a natural Fondneſs of their own Qualifications, and an Unwillingneſs to think any thing of which they are ignorant, neceſſary to the Science they profeſs, have generally recommended and extolled thoſe Parts which they beſt underſtood themſelves, but bantered and decryed thoſe they were *leſs skilled in, tho' not leſs neceſſary and uſeful. Natural Philoſophy and the Hiſtories of Diſeaſes muſt go hand in hand in the improving the Art of curing; it is not poſſible to make any uſe of the laſt without the Knowledge of the firſt. And I may venture to ſay, that there is no Man that practiſes, but who does it upon ſome Knowledge of the Animal Oeconomy, or ſome notions of his own which are more or leſs clear according to his Skill in natural Philoſophy. And for the Truth of this, I appeal to Dr.* Sydenham's *own Writings, who by his philoſophizing has evidently ſhewn us the Neceſſity of that Science, he ſo much decryed, and ſo little underſtood. He was undoubtedly a great Man, and the World will always be obliged to him for his accurate Hiſtories of Diſeaſes; but there is no Man without Errors, and where one of his deſerved Character* *falls into a Miſtake, it does a great deal more hurt, than if hundreds of others of leſſer Note had been guilty of the ſame.*

The following Treatiſes contain a few Thoughts about ſome of the principal Parts of the Animal Oeconomy; It was the Conſideration of the Uſe of the Vena Porta *which gave me the firſt hint to think that the ſeveral Humours of the Body were formed by the Attraction of the Particles of the Blood; which when I had communicated to my Brother, he was pleaſed to ſee his Theorems of Attraction illuſtrated by ſo eminent an Inſtance, and ſent me the Demonſtration of the third Propoſition.*

The firſt that I know of who, to explain Secretion, thought it neceſſary to conſider the ſtate of the Blood at different diſtances from the Heart, was the ingenious Dr. Cockburn; *and tho' he was not then aware of this*

this Principle of Attraction; yet he wiſely foreſaw that different Velocities of the Blood were requiſite for ſecerning of different Fluids.

As the Learned Dr. Gregory *has ſhewn us, in the Preface to his Aſtronomy, that the Gravitation of the Heavenly Bodies towards one another was known to the Ancient Philoſophers; ſo this Power by which the ſmall Particles of Matter attract one another was the Doctrine of* Hippocrates, *(a) whoſe whole Philoſophy is built upon a certain* Propenſion *which ſome things have to one another, whereby they* attract, retain *and* alter *one another.* Galen *(b) does aſſert this Attraction to be*

(a) Vide Mr. *Le Clerc*'s Hiſtoire de la Medicine.

(b) Præterea conſpirabile & confluxile totum corpus eſſe, Naturamque omnia juſtè & artificioſè peragere, facultatibus ſcilicet præditam, quibus ſingulæ particulæ convenientem ſibi ſuccum ad ſe trahunt, attractum verò coaleſcere, accreſcereque omnibus ſuis partibus faciant *cap.* 12. *lib.* 1. *de Natural. Facultat.* Oſtenſum

be an univerſal Power in Matter and (c) compares it to the Power by which a Loadſtone draws Iron. (d) Hippocrates *explains the manner that purgative Medicines operate juſt as we have done. And* Galen *in his Treatiſe* de Purgantium Medicamentorum Facultate, *does bitterly inveigh againſt all thoſe who in oppoſition to* Hippocrates *did aſſert that all purges, purged all Humours indifferently; and concludes that every purgative Medicine draws to its ſelf its proper Humour. And he ſtrenuouſly maintains a* Vis Attractrix *in Nature againſt* Epicurus, Aſclepiades, Eraſiſtratus,

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Oſtenſum eſt a nobis in Commentariis de Potentiis Naturalibus, Naturam uniuſcujuſque particulæ, quatuor uti potentiis, attractiva proprii alimenti, & ejuſdem retentiva. *Comment.* 1. *Aphor.* 22.

(c) Ergo ad quem modum trahatur in commune inveſtigemus: quo porro alio, quam ſicut a magnete lapide ferrum, qui ſcilicet talis qualitatis trahendæ vim habet. *Lib.* 2. *Cap.* 7. *de Natural. Facultat.*

(*d*) Τὸ γὰρ φάρμακον ὁκόταν ἐσελθῇ ἐς τὸ σῶμα, πρῶτον μὲν ἄγει, ὃ ἂν αὐτέω κατὰ φύσιν μάλιστα ᾖ τῶν ἐν τῷ σώματι ἐνεόντων. ἔπειτα δὲ καὶ τἆλλα ἕλκει τὶ καὶ καθαίρει.

ſtratus, *and others in his Book* De Naturalibus Facultatibus. *All which does ſufficiently ſhew that this Attraction of the ſmall Particles of Matter is no Innovation in Philoſophy.*

The manner by which I do ſuppoſe the Glands do ſeparate the ſeveral Humours from the Blood, is much the ſame with that of Dr. Morland's *publiſhed in the Philoſophical Tranſactions. What I have ſaid concerning the Quantity of Blood is ſufficient to ſhew how little reaſon common Opinions are ſometimes grounded upon. And the Difficulty of the Subject, and the new Method of handling it, will I hope procure this ſhort Eſſay a favourable Reception. The Theory of Muſcular Motion does follow ſo naturally and eaſily from the Principle of Attraction, that one would be almoſt tempted to believe it the genuine Method of Nature. The Determination of the* Vis Elaſtica *was the*

the Thought of the Learned John Bernouli; *but this way of demonſtrating it was communicated to me by my Brother: I am too ſenſible of my own Inabilities to purſue thoſe Thoughts which I have only ſtarted, and I ſhould be pleaſed if they were of any uſe to Men better qualified to make Diſcoveries in Nature.*

Tho' any one with a moderate Skill in the Mathematicks may underſtand theſe Diſcourſes, yet without that no one can judge of their Truth, and Uſefulneſs in explaining the Animal Oeconomy.

ESSAY I.

Of the Quantity of Blood in the Humane Body.

I Know not upon what Grounds Phyſicians and Anatomiſts have generally determined the Quantity of Blood in the humane Body, to be between fifteen and twenty five pound Weight. All that I can find is the large Quantities of Blood voided by Perſons dying of violent *Hæmorrhagies*; ſo that

How Dr. Moulin *did determine it.*

according to their ſeveral Obſervations, ſome have aſcribed a greater, and ſome a ſmaller Quantity of Blood to the Body. Dr. *Moulin* has allotted by much a ſmaller Quantity than any, and gives us the Method by which he determin'd it in the *Philoſophical Tranſactions.* He ſays, that in a Sheep, which alive, weigh'd 118 *lib.* be found by bleeding it to death, that it contain'd $5\frac{1}{4}$ *lib.* of Blood, which is leſs than $\frac{1}{22}$ part of the Weight of the Sheep. That in a Lamb weighing $30\frac{1}{2}$ *lib.* when living, there was but $1\frac{1}{2}$ *lib.* of Blood, which is about $\frac{1}{20}$ part: Now upon the Suppoſition, that a Man's Blood bears the ſame Proportion to his Weight, as that of the Lamb's (which is the greateſt) had to its Weight, it will follow that the Quantity of circulating Blood in a Man, weighing 160 *lib.* will not exceed 8 *lib.*

These Eſtimations (tho' widely different from one another) are both made from the Quantity of Blood voided at an open *Veſſel*; and they are both founded upon this Suppoſition, that almoſt all the Blood in the Body runs out at the Wound; a Suppoſition I can by no means allow to be true, and which I ſhall evidently ſhew to be falſe. For ſuppoſe the right external *Iliack* Artery cut aſunder, ſo as that the Blood may freely flow out of the Wound: How can the Blood which is in the right Leg below the Wound, be emptied? It is cut off from the reſt of the Blood above, which ſhould drive it forwards, and all the Aſſiſtance it can have from collateral *Branches*, which communicate with it can be but very little, becauſe they themſelves can receive but a very ſmall quantity of *Blood*, the *Blood* running all to the

Neither of theſe ways juſt.

Wound, where it finds the leaſt Reſiſtance. The Arteries in the *Leg* can beat no longer, becauſe the Pulſe depends upon the Quantity of *Blood* thrown into them every Syſtole of the Heart, which in this Caſe is nothing; and theſe being the only regular Cauſes of the Motion of the *Blood*, the *Blood* muſt ſtagnate in the Crural *Veſſels*. All that can be ſaid is, that the great Arteries will once contract, and may perhaps have ſome ſmall *Vibrations* afterwards, by which they will thruſt the *Blood* into the capillary *Veſſels*, and their convulſive Motions will ſqueeze the *Blood* forwards in the *Veins*; but when an Animal once falls into Convulſions by bleeding, it can bleed but little afterwards, the Motion of the Heart ceaſing; beſides we know, that neither all Animals, nor all Parts of an Animal are convuls'd upon bleeding to death: and tho' the great Arteries may contract, yet this Contraction muſt be very languid in the ſmall Arteries, which being innumerable, the greateſt part of the *Blood* will be lodg'd in them, there being nothing to drive it out of their contorted Channels, but it muſt ſtill remain in them, as likewiſe in the Fibres of the Muſcles, which appear of a red Colour, only upon the Account of the *Blood* contain'd within them, their Subſtance being naturally white. Again, tho' the right and left *Iliack* Arteries do in the natural State receive an equal quantity of *Blood*; yet when a Wound is made in the Right, thro' which the *Blood* has an eaſie Paſſage, this muſt receive much the greateſt part of the *Blood* which comes down the *Aorta*, and conſequently the Circulation of the *Blood* muſt be very ſlow in the left *Leg*, and no more *Blood* can come from it, than what is thruſt out meerly by the Motion of the *Body*, or what flows naturally of its ſelf in the ſtrait and large *Veſſels*, as Fluids will do to come to an *Equilibrium*; for the ſame Reaſon the aſcending *Trunk* or *Branches* of the *Aorta* can receive but a ſmall quantity of *Blood*, and therefore the Pulſe in the Arteries of the *Brain* muſt be very languid or none at all, upon which account the Motion of the Spirits muſt ceaſe, and conſequently that of the Heart. When the *Aorta* begins to be empty (which muſt quickly happen when the *Blood* runs out at a Wound of a large Artery) then the *Blood* having little or no Reſiſtance, will flow eaſily into the empty *Veſſel*, and a very ſmall Quantity of it will enter the Orifices of the Coronary Arteries of the Heart, the *Valves* covering them, and conſequently the Motion of the Heart muſt ceaſe for want of *Blood*.

The greateſt Effuſion of Blood not from the largeſt Veſſel.

It is for theſe two laſt Reaſons, that the larger the *Veſſels* are that are wounded, the ſooner the Animal dies; and if the *Aorta* it ſelf was cut aſunder, there would be a ſmaller Effuſion of *Blood* from it, than from a ſmaller Artery: For ſince it is the *Blood* in the *Aorta* that thruſts forward the *Blood* in the *Veins*, and makes it paſs from the *Vena Cava* into the right Auricle of the Heart; it is plain, that when the *Blood* in the *Aorta* is intercepted, the *Blood* will be no longer driven thro' the *Veins*, but will ſtagnate in them, no more of it coming to the Heart, than what by reaſon of the Fulneſs of the *Veins* flows into it, and conſequently the Heart throwing but a ſmall Quantity of it into the *Aorta*, the Circulation will be quickly ſtopt, both in the aſcending and deſcending Trunks, and there will be no greater Effuſion of *Blood* than what can be contain'd in the great Artery which holds but little. Whereſoever the Wound is made, ſo long will the Animal live as the great Artery keeps full, but whenever that begins to empty, the *Blood* in all its Branches muſt ſtop, and conſequently the Animal muſt die.

The greateſt Flux of Blood from the ſmalleſt Veſſels.

The *Veſſels* of the *Animal Body* are not meer unactive Tubes; but as they may be gradually dilated, ſo they can gradually contract again; and as they cannot ſuffer any violent and ſudden Stretching without breaking, ſo neither can they immediately contract upon any ſudden Evacuation. And therefore when any great *Artery* is wounded, the *Animal* dies after a few Pulſations of the Heart, the great *Artery* being immediately emptied: But when a ſmall *Artery* at a great diſtance from the Heart continues bleeding ſlowly, all the *Veſſels* throughout the whole *Body* gradually contract, ſo that after many Pounds are evacuated, they may be as full as they were at firſt, and conſequently the *Animal* not ſo much as faint, the *Veſſels* in the *Brain* being ſtill kept full, and the Spirits driven forwards in the *Nerves*; nor can the Animal die till ſuch time as the *Veſſels* contract no more. It is for this Reaſon that we have no Obſervations, which give account of ſuch large Effuſions of Blood at Wounds of the great Arteries, as we have from the ſmall *Veſſels* of the Noſe, and from the *Hæmorrhoides*; and therefore Doctor *Moulin's* Determination of the Quantity of the whole Maſs of Blood, which is calculated from the Quantity voided at the Carotide and Jugular *Veſſels*, is much leſs than what others from the Obſervation of *Hæmorrhagies* of ſmall *Veſſels* have determined it to be.

The Reaſon of fainting upon any ſudden Evacuation.

This Contractive or Elaſtick Power of the *Veſſels* is not equal in all Bodies; for in ſome it is greatly diminiſh'd by the Viſcidity of the Blood, and the Obſtruction in the Fibres and Capillary *Veſſels*; and therefore ſome Men may die of a much leſs effuſion of Blood than others, who perhaps may have a leſs Quantity of Blood. It is for the ſame Reaſon that ſome Perſons faint upon opening a *Vein* of the Arm, whilſt others do not. If this Elaſtick Power of the *Veſſels* is ſtrong and great, then as the Blood is let out, the Arteries of the *Pia Mater* contract, and are kept full as well as the Coronary *Veſſels* of the Heart, and conſequently there is neither Blood nor Spirits wanting for performing the Motion of the Heart; but it happens juſt otherwiſe, where this Elaſtick Tone of the *Veſſels* is wanting, that is, to ſuch as have a ſoft and looſe Fleſh, a lax and cachectick habit of Body; and therefore when they require bleeding, it is convenient to ſtop the Blood at ſmall intervals, to give the *Veſſels* time to contract, before the full Quantity that is deſign'd be drawn off; and if they are ready to faint, the ſurprizing them, by throwing cold Water in the Face, to cauſe a ſudden Contraction, and the putting of them into an horizontal Poſture, that the *Veſſels* of the Brain may fill, and the Blood from all the depending Parts, have a more eaſie Reflux, does prevent it. It is the want of the ſame Energy of the *Veſſels* that cauſes ſome to faint upon any ſudden Evacuation by Urine, Stool, or any other ways.

A Proof of this Reaſon.

That this is the true Reaſon of fainting upon any ſudden or violent Evacuation, and not the drawing off of the Spirits (as is generally ſaid) appears not only from this, that ſuch as faint upon bleeding at the Arm, do not faint upon Cupping, tho' the ſame, or a greater Quantity of Blood be drawn off this way, but likewiſe from the fainting of Perſons tapped for an *Aſcites*, if it happens, that too great a Quantity of the Waters is drawn off at once. None can ſuppoſe that the Spirits, which are in the extravaſated *Lympha*, have an immediate Influence upon the Nerves and Heart, that their Subſtraction ſhould preſently drain the Nerves of Spirits; nor can any think, that the Spirits are ſo quickly ſpent, as immediately to ſuffer upon the account of the want of a Supply from an extravaſated Fluid: but the Caſe is this;

In an *Aſcites*, the deſcending Trunk of the *Aorta*, and all its Branches being conſiderably compreſſed, the Blood muſt neceſſarily dilate the aſcending Branches beyond their natural Bigneſs; but, when the Waters are let out to any conſiderable Quantity at a time, the Blood has a more free Paſſage into the deſcending Trunk, the Sum of the Cavities of both Arteries is augmented, and the Quantity of Blood thrown out every *Syſtole* not being greater, the Arteries cannot be ſo much dilated, and conſequently the Pulſe becomes ſmall and weak, and the Spirits therefore are but ſlowly propelled thro' the Nerves, the Blood flows but in a ſmall Quantity into the Coronary *Veſſels* of the Heart, and conſequently a *Syncope* muſt enſue, till the *Veſſels* can recover their Tone, and the Blood in all the Arteries comes to an *Æquilibrium*, and therefore it is neceſſary to rarifie the Blood, and rouſe the languid Motion of the Spirits by a Cordial; or to compreſs the deſcending Trunk of the great Artery by compreſſing the *Abdomen*, as has been ſucceſsfully tryed by the learned Dr. *Mead*.

That the Compreſſion of the deſcending Artery muſt throw a greater Quantity into the aſcending Branches is demonſtration, and that this Quantity is conſiderable, and does affect the whole Machine, is evident from the Fluſhing and Head-ach which ſome feel after a plentiful Meal, when the Stomach and Guts being loaded, preſs upon the deſcending Trunk, and contract its Cavity, which are the Cauſes why a greater Quantity of *Blood* paſſes into the aſcending Trunks; on the contrary, if the Cavity of the deſcending Trunk ſhould be dilated,

lated, there will be a leſs Quantity of *Blood* thrown into the aſcending Trunks, and conſequently the Effects on the Animal *Body* muſt be at leaſt as ſenſible.

This contractive Power of the *Veſſels* ought to be duly conſider'd, before the leaſt Quantity of Blood be drawn in moſt acute, as well as chronick Diſeaſes; for I could eaſily ſhew how it may be loſt to a great Degree, in a few Hours. And in no Caſe whatſoever is the drawing off a large Quantity of Blood at a time juſtifiable, ſince it may be done more ſafely, and to as good Purpoſe at ſmall Intervals. It is evident from the following Theory of *Secretions*, that both the Quantity and the Quality of the *Secretions* may be alter'd by *Blood-letting*, and therefore when the *Blood* is upon a Ferment, and generates new Coheſions, of whoſe

The great Riſque in Bleeding and the uncertainty of its Conſequences.

Nature we are ignorant, it is a Riſque, which without evident and cogent Reaſons ought not to be run. But to return,

A greater quantity of Blood proved from the Obſervations of Phyſicians.

If we give any Credit to the Obſervations of Phyſicians, we muſt believe the Quantity of *Blood* in the Humane Body to be above 25 pound Weight. (*a*) *Rulandus* tells us, that he cured one of a bleeding at the Noſe, after he had bled in one Day about Ten pound Weight. (*b*) *Petrus Borellus* obſerves that a full bodied Jovial Taylor loſt Ten pounds of *Blood* by the *Hæmorrhoides*, and that he cured him with the Syrrup of dried Roſes. (*c*) *Sckenckius* quotes *Montanus* for one that voided Two pounds and more of *Blood*, by the Piles, every day for forty five days together, and

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(*a*) Rulandus Curat. 57. Cent. x.
(*b*) Cent. iv. Obſ. Lviii. (*c*) Lib. tert. Obſ. clx.

was

was afterwards cured. (*d*) *Bartholin* ſays, that he ſaw one vomit ſixteen pound of *Blood* without the leaſt ill Conſequence. And he takes Notice of one who bled forty eight pound in three Days by the Noſe, from *And. Argolus.* (*e*) *Sckenckius* has ſeveral Obſervations of profuſe *Hæmorrhagies* of the Noſe. He mentions a Nun of a thin Habit of *Body*, who by bleeding at the Noſe, ſpitting of *Blood*, and with Urine, voided eighteen pound of *Blood*; ſhe was cured by one Drachm of *Philonium Perſicum. Braſavolus* cured a Lady of a bleeding at the Noſe; the *Blood* which he weighed, beſides what fell upon the Ground, Linen and Cloaths, was eighteen Pound. *Marcellus Donatus* recovered one of a bleeding at the Noſe, who in two Nights

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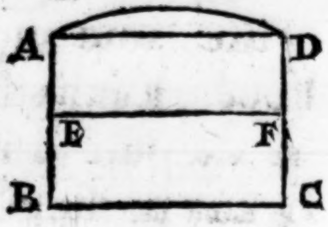
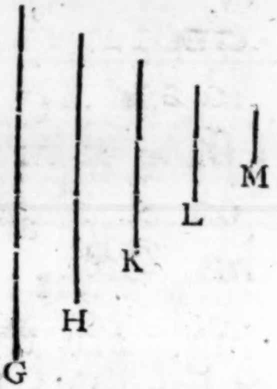
(*d*) Cap. de Corde.
(*e*) Lib. de Capite Obſ. cccxxxiii.

and one Day, bled above twenty pound Weight, as he found by weighing it. And at laſt he tells us of one who in ſix Days bled forty pound at the Noſe. In the *Acta Eruditorum Lipſiæ* for the year 1688, we have an Account of a young Man about 25 years of age, of a thin habit of Body, and a bilious Conſtitution, who after various Paſſions of his Mind bled at his Noſe in ten days time 75 pound of *Blood*, and was afterwards reſtored to a better health than he had before.

Now if the Quantity of *Blood* in the humane Body was not conſiderably greater than its common Eſtimate, theſe Perſons could never have ſurviv'd ſuch profuſe Effuſions of their *Blood*. All of them bled more than Dr. *Moulin* reckons to be in the Body, and many of them more, and almoſt double of the largeſt Quantity, which is allow'd of by any: So that either we muſt deny theſe Matters of Fact, or we muſt own, that our higheſt Eſtimates of the *Blood* fall much ſhort of the true Quantity. Without doubt Men differ in the Quantities of their *Blood*, as well as in the Weight of their Bodies: But none of theſe above-mention'd are noted to have been of a full habit of Body except *Borellus*'s Taylor; and it is particularly ſaid of the Nun in *Sckenckius*, that ſhe was a ſpare and thin Woman, and that her bleeding could not proceed from a *Plethora*.

That the Quantity of Blood is conſiderably larger than the common computation, will I think appear if we conſider the Quantity of our daily Evacuations, which in a ſettled State of health, when the Body is every day of the ſame weight, is the ſame in Quantity with our Food. Let us therefore ſuppoſe that we eat and drink four Pounds every day to ſupply our daily waſting, the Body may continue of the ſame weight. This Aliment equally mixing with the Blood, and being aſſimulated to it, will with it be ſecerned in the Glands, ſo that both old and new will go off together; I ſhall at firſt ſuppoſe in proportion to their Quantitys: Now in this Caſe, I would know how much of the old Blood remains in the Body after any certain ſpace of time. This Queſtion is the ſame as if you would ſuppoſe a Veſſel of Wine holding 200 quarts, and that out of it were drawn 4 quarts every day, and conſtantly filled up again with Water. *Quæritur* how much Wine will remain in the Veſſel at the end of any number of days?





Let ABCD repreſent the Veſſel at firſt full of Wine, and then let the Quantity AEFD be drawn out, then the firſt Quantity of Wine will be to the Wine that remains, as the Veſſel AC is to EC, that is as DC to FC; ſo that if the line G repreſent the firſt Quantity of Wine, and if G:H::CD:CF, H will repreſent the remaining Wine after the firſt drawing. And being the Veſſel is ſuppoſed to be filled up again with Water, and both Wine and Water equally mixed together; the Quantity of Wine that is drawn off the ſecond time, will be as the Quantity of Liquor that is drawn off; and the Quantity of Wine that remains, will be as the Quantity of the remaining

Liquor, that is as CF; or the Wine that remains after the firſt drawing will be to the Wine that remains after the ſecond drawing, as DC to CF. And if H : K : : CD : CF, then K will repreſent the Wine remaining after the ſecond drawing, and G, H, K, will be continual proportionals. After the ſame manner if K : L : : CD : CF, L will repreſent the Wine remaining after the third drawing, and the Quantities which ſhew what remains after each drawing, are the terms of a *ſeries* of Geometrical Proportionals.

Now let us ſuppoſe the Quantity of Blood in the Body to be only 20 *lib.* then we have a *ſeries* of Geometrical Proportionals, whoſe common *ratio* is 20 to 16, or 10 to 8. If therefore we take the firſt Term to be 1, the ſecond will be 1.25. whoſe Log. 0.0969100 multiplied by 30 (the number of days in a month) is 2.9073000, which ſubſtracted from the Log. of 20 (the number of Pounds of the Blood) *viz.* 1.3010300, gives the Log. of the 30*th* Term 8.3937300, to which the number anſwering in the Tables is 0.024758; and therefore after 30 Days the Quantity of old Blood remaining in the Body will be the 0.024758 part of a Pound, which in a little more than three Drachms. This is a quicker change of Blood than I believe ever entered into the imagination of any man; and I am apt to think that every one who reads it, will readily ſave me the trouble of diſproving what at firſt ſight is altogether incredible. If therefore our Evacuations are only from the Blood, the Quantity of the Blood muſt be much more than 20 *lib.* But thoſe who aſſert that the Blood is 20 *lib.* only, will I ſuppoſe ſay that the great Quantity of our Evacuations comes from the decaying and waſting of the ſolid parts. Let us therefore ſuppoſe that a Body which contains 20 *lib.* of Blood weighs 160 *lib.* we will examine how much of the old Body muſt remain at the years end. If we waſte every day 4 pounds, the *ratio* of the Terms will be 160 to 156, or 80 to 78. If therefore the difference of their Log. be taken and multiplied by 365, the days of a year, and the Product ſubſtracted from the Log. of 160, there will remain the Log. of the 365*th* term of the *ſeries*, which ſhews the Quantity of the old Body remaining, and it amounts to 3 Drachms. Now can any one believe that our Fleſh and ſolid Parts change almoſt all every year? And yet even in this Caſe there will not remain at the years end 20 Grains of the old Stock of Blood.

There is one thing farther to be conſidered before this argument can be ſaid perfectly to conclude, and that is, whether or no this great Evacuation may not proceed from our Aliment its ſelf. I own I do think that it does in a great meaſure, and I am willing to make any reaſonable allowances for it, and then let us ſee what the Conſequences will be. I ſhall therefore ſuppoſe that of the 4 *lib.* which we eat and drink, 3 *lib.* goes off immediately, that is, the ſame day; and then the Caſe is the ſame as if our Suſtenance weighed only one pound, and our Evacuations were of the ſame Weight. Now if upon this ſuppoſition we enquire how much of the old Stock of Fleſh and Blood remains at the years end? the Anſwer will be little above 16 *lib.* of which two pound is Blood, if that was at firſt only 20 *lib.*

and 126 *lib.* of ſolid Fleſh muſt have waſted in a twelve months time, which it is hard for common ſenſe to believe.

But if we puſh this Conſideration of the greateſt part of our Aliment being excrementitious a little farther, we ſhall find our Argument ſtill ſtronger. For let us ſuppoſe that $\frac{1}{8}$ part of it only is fit to be aſſimulated into Fleſh and Blood, and undoubtedly conſidering our Food is partly made up of the Parts of animal Bodys, and partly of Vegetables, which are compoſed of Tubes analagous to thoſe of the animal Body, it muſt be granted to be a very fair allowance. And indeed it can hardly be imagined that Nature in providing us with a proper Aliment, ſhould burthen our Stomach, Digeſtion and Blood with 7 Parts in 8, of what was only fit for Excrement. However, I ſhall ſuppoſe that only ½ *lib.* of what we eat and drink in a day is fit to be converted into good Blood. This half pound of freſh and good Blood thus purified from all excrementitious Particles, muſt neceſſarily be fit for all the uſes of the animal Body , and when converted into Fleſh, muſt remain good and ſound, without decaying, as long as any Parts can do. Thus thoſe Parts which have been longeſt in the Body will decay and waſte firſt, and thoſe which were laſt added will remain the longeſt. If therefore the Body continues of the ſame Weight, there muſt go off half a Pound of the old Body to make way for the half pound of good nutritious Blood added every day, and ſo in leſs than a year the whole Body muſt be changed. Thus I have conſidered the ſeveral ſources which can be ſuppoſed to ſupply our daily Evacuations, and do find that upon ſuppoſition that the Quantity of Blood in the Body is no more than 20 *lib.* that the Conſequences are ſuch as are beyond all Credit; for can any man believe that either almoſt all the Blood changes every month, or all the ſolid Parts of the Body every year? and yet theſe are the Conſequences of ſuppoſing the Quantity of Blood to be but 20 *lib.* Weight. It does indeed neceſſarily follow from the foregoing reaſonings that the Body changes much oftner than was commonly thought. The vulgar opinion gave 7 years to complete a thorough Change of the Body; but for any reaſon alledg'd it might as well have requir'd 70. Now it appears that the Change is almoſt yearly, nor is there any thing incredible in this, if we ſuppoſe that the Bulk of the Body is Blood, and that the ſolid Parts, make up but a very ſmall Part of it, and that theſe ſolid Parts, how great or little ſoever they are, ſeldom if ever change, ſome Reaſons incline me to believe.

For firſt, the Scars of the Cuts which Children receive in their Fingers and Faces never wear out when they are old. The Marks of the Lance in bleeding always remain in the Arm, as do likewiſe the Inciſions made by cupping. The Pits and Seams of the ſmall Pox in a Child of a year old, ſpoil the Beauty of the Face at fifteen, and add to the Wrinkles of old Age. Nay all theſe Marks and Scars, inſtead of wearing out, as the Skin extends they are every way extended with it; and a Scar which in a Child was not half an inch long, comes to be above an inch when the Perſon is at full growth; and as it ſtretches in length ſo it does in width proportionably. Now if the ſolid parts of the Body were continually waſting and changing, theſe Cicatrices would daily grow leſs and leſs, and at laſt totally diſappear; new Particles filling up the place of the wounded ones as they decayed; but we find it quite otherwiſe, and therefore the Parts in which theſe Wounds were made always remain the ſame.

Another Argument to prove that the ſolid Parts of the Body are always the ſame, may be drawn from the Spots and Stains which are made in the Skin by Gun-powder, and other Mixtures, ſuch as are uſed in ſtamping the Skin at *Jeruſalem*, or as ſome *Indians* uſe in painting of their Bodies, and ſome amongſt our ſelves to make Spots in their Hands. For if the ſolid Parts which are tinged with theſe

Mixtures waſted and decayed, the colouring would with them likewiſe decay. The new Particles which are ſuppoſed to come in the room of the old decaying ones, tho' they may have the ſame Figure and Dimenſions with thoſe whoſe places they fill up, yet they cannot be ſuppoſed to have the ſame artificial Tincture: But theſe Stains generally remain for ever; and therefore the Parts ſo ſtained, are always the ſame without changing. From all which it follows, that our Bodies change much oftner than was ever imagined; that this Change is not of the ſolid Parts of the Body, but of the Blood; and that the Quantity of Blood muſt be vaſtly greater than the common Computation makes it to be. If it ſhould be objected to this quick Change, that we ſometimes find it very hard, after many years application to cor-

and amend a vicious *Craſis* of the Blood; the Anſwer is eaſy, That as the new Juices mix with the old, they are aſſimulated into the ſame nature with the old, and are tainted with its Qualities. A little Ferment will affect a great Maſs of Fluids; and from thence it comes, that in ſome chronick Diſtempers, in which the Blood is apt to breed the ſame vicious ſort of Humour, after a long and judicious *Regimen* carefully obſerved, when the Blood is purified, and the Body reduced to a good State of Health; yet if the Quantity of a Grain remain of the noxious Humour, that ſmall Quantity will in proceſs of time taint the whole Humours in the Body, and the Diſtemper return as bad as before. Now tho' the old Stock of Blood (as has been ſhewn) daily leſſens, yet it never can be totally purged out of the Body; for being equally mixed and diluted with the new Blood, ſome of it muſt always remain, whilſt there is any of the other. And from thence proceeds the Difficulty of rectifying ſome bad Conſtitutions, the ſame humour will ſtill be growing upon you, reduce it never ſo low, unleſs it is totally eradicated; and that it never can be totally eradicated by by all or any one ſort of Evacuation, is likewiſe evident from what has been ſaid. Indeed Salivating, or proper Purges adapted to the nature of the Humour, when the Blood overflows with it, may at firſt be abſolutely neceſſary, and cut off a great deal of labour; but then as the Humour grows leſs, every days Evacuation carries off leſs and leſs, and can never poſſibly draw all off. If therefore we would complete the Cure, the Patient muſt continue a long time in the uſe of alterative

Medicines, that the Nature of that Humour may be changed which could not be carried off.

Having therefore ſufficiently proved that the Quantity of Blood in the Humane Body muſt be much greater than the common Eſtimation: I ſhall in the next place endeavour to ſhew how much at leaſt it is.

What is here meant by Blood.

By Blood I underſtand not only the Fluid in the Veins and Arteries, but likewiſe that in the *Lympheducts*, *Nerves*, or any other *Veſſel* of the Body, becauſe they are all Parts of the Blood, ſeparated from it by the force of the Heart, and many of them by the ſame force return to it again; and therefore, when I ſpeak of the Quantity of Blood in the Body, I would be underſtood to mean the Quantity of circulating Fluids, of what kind ſoever they be: At other times I ſhall uſe the Word in its common Signification.

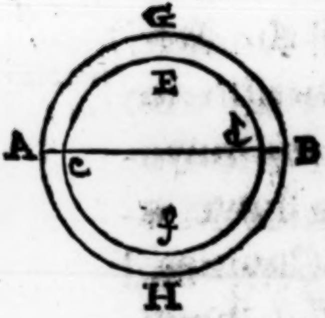
The whole Body made of Veſſels and Fluids.

I ſuppoſe the whole Body is nothing but *Tubes* or *Veſſels* full of *Blood* or *Liquors* ſeparated from it. This is now agreed on by all who underſtand the Fabrick of the Body, and is evident from nice Mercurial Injections of the *Veſſels*, and may be plainly ſeen by *Microſcopes*. *Leeuwenhoeck* ſays, that there ſeemed to be above 10000 Blood-veſſels in the ſpace of $\frac{1}{4}$ of an Inch ſquare. You cannot prick your Finger with the fineſt Needle but it wounds a Blood-veſſel. The Fibres of the Muſcles (which make by far the greateſt part of the Body) are full of Blood, and the Fibres of the Bones, are not without their Fluid, as I ſhall ſhew afterwards.

The Proportion of the Fluids to the Veſſels.

I therefore conſider the *Veſſels* full of Fluids, as ſo many ſolid *Cylinders*, and the Coats of the *Veſſels*,

ſels, as ſo many concave *Cylinders* of the ſame height, whoſe proportion to one another may be thus determined. Let A B G H repreſent the circular Section of a Veſſel, of which call the Diameter A B, *a*, the Diameter *c d* of the Cavity, $a-b$. Circles being to one another as the Squares of their Diameters, the Square of the whole Section is a^2, the Square of the Cavity is $a^2-2ab+b^2$, which being ſubſtracted from the Square of the whole, there remains $2ab-b$ proportional to the annular Space A B G H *c d f* E, and conſequently in a Body compos'd of ſuch *Veſſels*, filled with Fluids, the Fluids will be to the Solids, or Coats of the Veſſels as $a^2-2ab+b^2$ is to $2ab-b^2$.



Several ſorts of Veſſels.

Now if the whole Body was compoſed of Veins or Arteries, it were eaſie to determine the Quantity of Blood in the Animal Body. But we find, that the Coats of the Arteries have a greater Proportion to their Cavities, than the *Veins* have to theirs; and theſe again have a greater Proportion to their Cavities, than the *Lymphatick Veſſels* have to theirs; and there may be one Proportion of the Nerves, another of the Fibres of the Muſcles, and another of the Fibres of the Bones; all which ought to be known before the Quantity of Blood in the animal Body, can be exactly determin'd.

The thickneſs of the Coats of the Blood-veſſels may be thus exactly found, Slit a piece of a Blood-veſſel, and reduce it to the Form of a *Parallelogram*, then weigh it in Water, and by that means find the Weight of Water equal to it in bulk. This Weight reduced to decimal Parts of an Inch call, *d*, and ſuppoſe the length of the *Parallelogram* equal to *e*, and its breadth $=c$, its thickneſs *f*. Then $d=ecf$ and conſequently $\frac{d}{ec}=f$ the thickneſs of the Coat of the *Veſſel*.

The Proportion of the Blood in the Arteries to the Coats of the Arteries.

Thus a piece of the *Aorta* of a Calf I found to be equal to 0.071897 parts of an Inch [illegible] Water, its length was 1.1, its breadth 1.28, and therefore its thickneſs was 0.051. The Diameter of the Cavity of this Artery was 0.407. and conſequently $a^2-2ab+b^2$ equal to 0.165649, and $2ab-b^2$ equal to 0.093432, and therefore if the whole Body was compoſed of Arteries or Veſſels which had the ſame Proportion to their Cavities, as the Arteries have to theirs, the Blood would be to the ſolid part of the Body, as 1.7 to 1, and a Body weighing 160 Pound, would have 100 Pound of Blood.

The Proportion of the Blood in the Veins to the Coat of the Veins.

After the ſame manner I found that the thickneſs of the Coats of the *Vena Cava* of the ſame Calf was 0.0097. The Diameter of this *Vein* was 0.617, its Square is 0.380689, and $2ab-b^2=0.0243$-1596. If therefore the Body was compoſed of Veſſels whoſe Coats had all the ſame Proportion to their Cavities, that the Coats of the Veins have to theirs, the Blood would be to the ſolid part of the Body, as 15.6 to 1, and in a Body weighing one hundred and ſixty Pound, there would be above one hundred and fifty Pound of Blood.

How the Bulk of the Blood encreaſes upon a ſmall encreaſe of the Diameter of the Blood-Veſſel.

It is to be obſerv'd, that theſe Proportions of the thickneſs of the Coats of the *Veſſels* to their Cavities were taken when the *Veſſels* were empty, and conſequently when the Coats were thickeſt, and the

Diameter leaſt, for all the *Veſſels*, eſpecially the Arteries, ſhrink and contract when they are empty. Let us ſuppoſe the Diameter of the Cavity of the Artery which was 0.407, to be encreaſed 0.1, the Square of this Cavity would be 0.257049, and conſequently the Blood would be to the ſolid part of the Body, as 2.7 to 1. If the Diameter were increaſed 0.2 the Blood would be to the *Veſſels*, as 3.9 to 1. If 0.3, it would be as 5.3 to 1. From theſe Proportions one may judge more exactly to what Degree the Blood is heated or rarified in inflammatory Fevers, by the Largeneſs of the Pulſe: As alſo how ſmall a Quantity of Blood muſt be thrown out at the Heart every *Syſtole* in languid Fevers when the Pulſe is ſmall.

How the Arteries may be dilated in Aneuriſms.

It is ſurprizing to ſee how little the encreaſe of the Diameter of the Cavity of the Artery diminiſhes the thickneſs of its Coats; for if we add to the Square 0.257049, the annular Space, which we found to be 0.093432, then 0.350481 is the Square of the Diameter of the whole Artery, that is both of its Coats and Cavity. The Square Root of this Number is 0.592, from which if we ſubſtract the Diameter of the Cavity, there remains 0.085, the half of which 0.0425 is the thickneſs of the Coat of the Artery. Thus I find that the Diameter of the *Aorta* may be encreaſed eight times its firſt bigneſs before its Coats become ſo thin as the Coats of the *Cava*. This ſhews how prodigiouſly Aneuriſms may dilate the Arteries; and how when a large Trunk of an Artery in the Arm, Leg, or Thigh, is tied, the ſmall Arteries (which all communicate with one another) may dilate to carry on the Circulation of the Blood.

Of the Quantity of the Blood in the Fibres of the Muſcles.

The next ſort of *Veſſels* I come to conſider is the Fibres of the Muſcles, which tho' they may be more bulky, yet they cannot be more numerous than the Arteries; for every Fibre muſt have at leaſt one Artery, and it is probable it has ſeveral. They without doubt have conſiderable Cavities, being they ſwell, are blown up, and thereby conſiderably ſhortned when the Muſcles act. And their ſides can be but thin, or elſe they could not be diſtended by ſo ſmall a Force. Beſides the Blood appears as plainly thro' them, as it does thro' an Artery of an equal bigneſs, and therefore we cannot judge their ſides to be thicker than the Coat of an Artery of an equal bigneſs. The Proportion of the thickneſs of their ſides to their Cavities is not to be taken after the manner we have done thoſe of the Veins and

Arteries; but that we might make ſome Eſtimate of it, I made the following Experiment.

I took a piece of the Inteſtine of a Dog, with part of the Meſentery and *Pancreas Aſellii*, and having carefully emptied it of all its Contents, I weighed it exactly with all the Blood in the Veſſels, its Weight was one Ounce and a half, one Drachm and eighteen Grains; then I injected warm Water into the Artery, and having ſufficiently waſhed out all the Blood, I blew it up, and hung it up to dry in the Shade; after it had dried about a Week, I weighed it again, and its Weight was two Drachms, two Scruples, and eleven Grains: By which it appears, that it had loſt 627 Grains, and that there remained only 171 Grains. Now this Loſs could be only of the Fluids, which being diluted with the warm Water, were the more eaſily evaporated, and therefore if the Blood in every part of the Body bore the ſame Proportion to the ſolid part, that it does to the ſolid part of the Inteſtines, their Proportions would be 3.6 to 1, and a Body weighing one hundred and ſixty Pound would contain one hundred and twenty five Pound of Blood, ſo that even the Fibres of the Muſcles are leſs ſolid than the Arteries. But the Fibres which perform the Periſtaltick Motion of the Inteſtines, are not ſo ſpongy as the Fibres of the Muſcles, for we find them firmer and harder; beſides, if we conſider that the Periſtaltick Motion is perform'd by a very ſmall Contraction of the Fibres, for which a very ſmall Inflation will ſuffice; but the Contraction of the Fibres of the Muſcles being great, they muſt be conſiderably inflated, and conſequently more ſpongy, and capable of receiving a larger Quantity of Blood, than the Fibres of the Inteſtines; and therefore it is evident, that in the Muſcles which make up far the greateſt part of the Body, the Proportion of the Blood to the ſolid Fibres muſt be above 3.6 to 1. or almoſt as 4 to 1.

Of the Quantity of Fluids in the Nerves.

To know what Proportion the Fluids of the Nerves bear to the ſolid part of the Nerves. I dried a piece of the *Medulla Spinalis* without any Art or Preparation, excepting the ſlitting of it; and I found that it loſt near $\frac{3}{4}$ths of its Weight, ſo that it appears, that even the Nerves are not more ſolid than the other Parts. And as to the Lymphatick *Veſſels*, I believe every one will eaſily agree that the Fluids in them bear a much greater Proportion to their Coats, than what has yet been found.

The

Of the Quantity of Fluids in the Bones.

The Bones of all the parts in the Body ſeem to bid the faireſt for Solidity, and yet even their Fibres are not without their circulating Juices; what elſe is the *Callus* which unites and cements the Extremities of broken Bones? In it there are no Fibres, nor parts to be diſtinguiſhed, but it appears like an uniform inſpiſſated Juice. At what ever time or age the Misfortune of a broken Bone happens, this Juice is always at hand, which ſhews, that it is always circulating, tho' ſlowly: If it ſtagnated, it would harden, as it does when it is extravaſated, and forms a *Callus*; and conſequently all the Paſſages being obſtructed, no broken Bone could unite. This Juice is like to the viſcous Sap of Trees; for without doubt a Fluid may move as eaſily thro' the Fibres of the Bones, as thro' the Fibres of an Oak. The Excreſcencies of the very Subſtance of the Bones, their Nodes, Swellings, and ſoftning like Wax, of which there are ſeveral inſtances to be found in Authors, even of Perſons grown in Years, do ſufficiently evince a fluid circulating thro' their Fibres. No doubt but that the older we grow, the narrower are the Channels of the Fibres, the viſcid Fluid hardening towards their Sides, and after Death intirely obſtructing them, ſo that the whole Fibre appears ſolid; but ſtill it is really no part of the Fibre, no more than the Cruſt with which ſome Waters line the Pipes thro' which they run, is part of the wooden or leaden Pipe, or the Glew in which a Sponge has been ſoaked, can be ſaid to be part of the Sponge: And as theſe may be taken out, without taking away any of the Subſtance in which they are contained, ſo likewiſe may this Fluid in the Bones. What elſe is the Jelly made of Harts-horn, but a Fluid extracted by boiling Water, the Fibres and Subſtance of the Horn ſtill remaining undiſſolved? Is not the Jelly extorted by *Papin's* Digeſter out of dry and ſolid Bones the ſame Fluid? That I might know what Proportion it bears to the Fibres of the Bones, I cauſed the Bone in the Knuckle of Beef, being firſt boiled and the Marrow taken out to be put in the Digeſter. Before it was put in, it weighed 22 Ounces 6½ Drachms, when it was taken out and dried, it weighed 11 Ounces 1½ Drachm, ſo that it loſt above half its Weight; and yet the Texture of the ſmalleſt Fibre in the moſt ſpongy part of the Bone was not broken, and the middle or more ſolid part appeared to be made of Parallel *Laminæ*, of which four or five would hardly exceed the thickneſs of a Sheet of Paper. And I doubt not but that if the Experiment had been made upon younger Bones, the Proportion of the Fluids to the ſolid part would have been found to be much greater. Now if the Bones contain ſuch a Quantity of Fluid, what do the *Tendons*, *Membranes*, *Ligaments* and *Cartilages*, which are much ſofter Subſtances, and which upon boiling likewiſe yield a Jelly? And is not Glew which is extracted out of the Skins of Animals ſuch a ſort of Fluid? So that it is highly probable, that there is not a Fibre in the whole Body, in which ſome Fluid or other does not circulate, but which hardening after Death, and perhaps ſome part of it before, no Elixation whatſoever can extract.

The Coats of the Veſſels compoſed of other Veſſels.

Thus have I conſider'd the ſeveral ſorts of Subſtances in the Body, and ſhewn what Proportion the Fluids in each of them bear at leaſt to their ſolid parts; I ſay at leaſt, for no Preparation nor Art can extract a Fluid ſo viſcid, and ſo apt to harden, as the *Blood* is, out of the innumerable Meanders of ſuch infinitely ſmall *Veſſels*. I have alſo ſuppoſed the Coats of the *Veins* and *Arteries* to be perfectly ſolid, that is, without Fluids, whereas it is evident to the naked Eye, and agreed on by all *Anatomiſts*, that they are compoſed of *Myriads* of *Veins* and *Arteries*. What an innumerable company does an inflammation of the Eye ſhew upon the *Tunica Conjunctiva?* and are there not many more to be diſcover'd by *Microſcopes*, and the finer the Glaſſes are which we uſe, ſtill the more *Veſſels* we diſcover; ſo that if we can ſee no more, it is only becauſe our Glaſſes are not better. Whoſoever

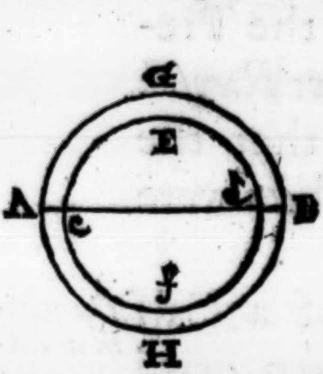
ſoever is acquainted with the Preparations of the curious Dr. *Ruyſck* would be apt to believe that the whole Body, and all its Fibres were nothing but *Blood-Veſſels*.

The quantity of Fluids in the Coats of the Arteries determined by an Experiment.

A piece of the *Aorta* of a Calf weighed 240 Grains, when dried it weighed 80 Grains; ſo that from this Experiment it appears, that the Blood in the Coats of the Arteries is to the Coats as 2 to 1, which is a greater Proportion than the Blood in the great Arteries bears to their Coats, and yet we cannot ſuppoſe that any more than the thin part of the Blood was exhaled.

A general Method to determine the quantity of Fluids in the Coats of the Veſſels.

Now therefore ſuppoſing that the *Veſſels* are made up of others, full of Fluids, and that there is the ſame Proportion of the Fluids to the ſolid parts in each of them; the Quantity of Blood in the Body may be thus determined. Let the Annular Space GABH,



GABH, *Ecfd*, be to the whole Circle AGBH, as 1 to a, then in a Body compoſed of ſuch *Veſſels* filled with Fluids, the Fluids will be to the Solids (if the Annular Space is ſolid) as $a-1$ to 1. But if this Annular Space is likewiſe compoſed of the ſame ſort of *Veſſels*, then in the whole Body the Fluids will be to the Solids as a^2-1 to 1: and again, if theſe leſſer *Veſſels* are compoſed of others ſtill leſs than themſelves, then the Fluids will be to the Solids as a^3-1 to 1: and if there ſhould be four ſuch orders of *Veſſels*, the Fluids will be to the Solids, as a^4-1 to 1, if five, as a^5-1 to 1: if ſix, as a^6-1 to 1: ſo that the Proportion of the Fluids to the Solids may be increaſed *in infinitum*. In the Arteries a is equal to 2.7, in the *Veins* it is equal

qual to 16.6, and according to the ſeveral Series of *Veſſels*, the Blood will be to the ſolid part of the Body in theſe Proportions.

1.7	to 1	15.6	to 1
6.2		274.5	
18.6		4573	
52.1		75932	
142.4		1250492	
286.4		20758082	

If the Body is compoſed of *Veſſels*, whoſe Coats are made of other *Veſſels*, and theſe again of others, as has been ſaid; then the Bodies of the *Animacula in ſemine*, or the *Prima Stamina Vitæ* may be increaſed to any bulk, and the Coats of the *Veſſels* ſo far as we can diſcern grow thicker and thicker, without the Addition of any Subſtance to the *Veſſels*, only by increaſing the Quantity of Fluid, with which they are

That all the Solids in an animal Body at full growth may be no more than what was in the Animalcula in ſemine.

are filled. For as the large *Veſſels* ſwell, ſo likewiſe muſt the ſmall ones, of which their Coats are compoſed, down to the very laſt; and the ſwelling of the ſeveral Orders of *Veſſels* muſt neceſſarily increaſe the Thickneſs of the Coat of that *Veſſel* which they compoſe: So that by increaſing the Number of the Orders of the *Veſſels*, the Coats of the firſt Order of *Veſſels* may be increaſed to any Degree, and yet the Diameter of the *Veſſels* which compoſe theſe Coats not greater than a given Line.

That the Coats of the great *Veſſels* are compoſed of ſmaller *Veſſels*, is Matter of Fact; and we know nothing to the contrary, but that theſe ſmall *Veſſels* may be compoſed of others ſtill ſmaller than themſelves. We know not how many *Laminæ* or *Folds* there are in any Membrane of the Body. That excellent Anatomiſt Mr. *Cowper* informs us, that every Membrane is Veſicular, and may be blown into innumerable Cells. That tranſparent Membrane the *Cornea* of the Eye conſiſts of as many parallel *Laminæ*, as the niceſt Hand of the moſt expert Anatomiſt can raiſe. That delicate thin Membrane which involves the *Brain*, divides its ſelf into two *Laminæ*. And it is very probable, that the *Hydatides*, of which ſeveral are found within one another, are nothing but the Coats of the *Lymphatick Veſſels*, diſtended and ſeparated by the *Lympha*, and yet it is hard to conceive any thing thinner than the Coat of a Lympheduct, which is not viſible but when it is diſtended with *Lympha*. If we know not the Number of *Laminæ* which compoſe the Membranes, how can we reckon the Number of Fibres, of which the *Laminæ* conſiſt? Or how ſhould we diſcover the Number of Fibres, of which each Fibre is made up? *Leeuwenhoeck* tells us, that the Fibre of a Muſcle which was nine times ſmaller than a hair of his Beard was made up of a hundred ſmaller Fibres, and yet each of theſe muſt have had Nerves, Veins and Arteries, and perhaps each of them made up of a hundred more: For how many Series of *Veſſels* any one *Veſſel* is made up of, is what no Microſcope can diſcover; becauſe only one Order can lie at a time in the *Focus* of the Glaſs, and if more could, their ſeveral Refractions would confound the Sight.

As it is certain that all the larger *Veſſels* are compoſed of leſſer ones, and highly probable that theſe leſſer are made up of ſuch as are ſtill leſs, and that there may be ſeveral gradations of *Veſſels* leſs than one another in the Fabrick of every larger *Veſſel*; ſo there are ſome inſtances which ſeem to prove that the parts of the Body may be increaſed almoſt to any bigneſs without the addition of any ſolid Subſtance, only by the ſwelling of the ſeveral orders of *Veſſels*. I ſhall give one very remarkable and evident inſtance of this kind, and that is the *Uterus*, which in Geſtation is diſtended to a very great degree; and as it increaſes in bulk, ſo its Coats grow thicker and thicker; and yet all this is without any addition of Subſtance to that of the Womb, its *Veſſels* being only ſwelled by the Affluence of Blood; for after Delivery theſe *Veſſels* ſubſide again, and the Womb becomes leſs again; tho' not ſo little as it was at firſt, becauſe the *Veſſels* of which it is compoſed are more dilated, and the Blood ſtill maintains a freer

Circulation than at firſt. Another inſtance of this kind is the Breaſts, which are increaſed conſiderably by the Flux of Milk, and which ſink again as the Milk goes away. We might likewiſe obſerve that in an *Aſcites* as the *Peritoneum* is diſtended, ſo it increaſeth in thickneſs; and thoſe who are converſant in Diſſections, know that all Membranes which are preternaturally diſtended, become always proportionably thicker.

Nutrition nothing but Diſtention.

If all the ſolid part of the Body was contained in the *Animalcule*, then *Accretion* and *Nutrition* are nothing but the Repletion and Diſtention of the *Veſſels*, and it is eaſie to conceive how *Helmont*'s Tree grew from five Pound Weight in five Years time, to one hundred and ſixty nine Pound, only by the addition of Water. Nor does this at all contradict the Ingenious

Dr. *Woodward's* Experiments concerning Vegetation, but his Experiments are rather a Confirmation of this Doctrine. For the fewer terreſtrial Particles are contained in the Water by which any Plant is nouriſhed, the quicker the Water paſſes off thro' the Pores or Excretory Ducts of the Plant, and conſequently the leſs the *Veſſels* are diſtended; but if the Water is impregnated with a large Quantity of terreſtrial Matter, it cannot paſs off quickly, but being retained in the Plant, the *Veſſels* muſt be diſtended, and conſequently the bulk of the Plant increaſed. That the fewer terreſtrial Particles the Water contains, the quicker it paſſes off, is evident from Experiments: For two Plants of Mint near of the ſame Weight, ſet at the ſame time, the one in Rain-water and the other in *Thames*-Water (which is more ouſly ſtored with terreſtrial Matter) this did thrive to almoſt double the bulk of that, and with a leſs Expence of Water; yet the Experiments do ſufficiently evince, that Plants require a proper Nouriſhment, as well as Animals, without which they can never kindly thrive. For Life is continued, and all its Functions performed by the ſtraining off of ſeveral ſorts of Juices from the common Fluid, which in Animals is called Blood: But if this common Fluid cannot afford theſe Juices, or is not fit to be turned into them, then that Body whether vegetable or animal, muſt turn ſickly, and at laſt die. Some ſorts of Water are more eaſily tranſmuted into the Juices of ſome Plants than others, for we ſee ſome love a very dry and ſome a very wet Soil, and ſome will grow in Water alone, and therefore it was that *Helmont's* Willow Tree grew to ſuch a bulk.

No equivocal Generation.

If the moſt proper Food can only diſtend but not increaſe or add to the Subſtance of the ſolid part of the Body, how much more reaſonable is it to ſuppoſe that no Matter, howſoever diſpoſed, can at firſt frame theſe ſolid parts, without an Omnipotent Power immediately actuating it.

The Poſſibility of the Reſurrection of the ſame Body.

And does not all that has been ſaid demonſtrate not only the Poſſibility but likewiſe the great probability of that Suppoſition, which the Reverend and Learned Mr. *Clark* uſes to ſhew the Poſſibility of the Reſurrection of the ſame Body; for if all the ſolid parts are no more than the Original *Stamina*, and all Nouriſhment only a Fluid in a perpetual Flux, then no part of an animal Body can become part of another animal Body; but the Body is always the ſame, from the firſt Moment of Life to the laſt.

The Weight of the Fat and Bones deducted from the Quantity of Blood.

But whether the Coats of the *Veſſels* are compoſed of others, or not, the Experiments I have brought do clearly demonſtrate that the Fluids in the Body are to the Solids at leaſt as 3.9 to 1, and therefore in a Body weighing one hundred ſixty Pound, there muſt needs be one hundred twenty ſeven Pound of Blood. From which Quantity, that I may put the matter out of all manner of Diſpute, I ſhall deduct the Weight both of the Fat and Bones, tho' I think that ſome Arguments might be alledged to prove that even the Fat circulates, and I have already ſhewn that there is a Fluid in the Bones.

In a Body weighing one hundred ſixty Pound, I ſhall ſuppoſe that the Fat is an Inch deep all round the Body, and in ſuch a mean

Weight, I believe this will be ſufficient to anſwer for all the Fat every where elſe. Dr. *Wainewright* reckons the Surface of the Body meaſures fifteen ſquare Feet, and therefore the Fat muſt be one hundred eighty cubick Inches. Now a cubick Inch of Fat weighs about half an Ounce or ſomething more, and therefore the whole Fat of the Body of a Man weighing one hundred ſixty Pound is ninety Ounces, or five Pound ten Ounces; but I ſhall ſuppoſe it to be ſeven, and that the Bones weigh twenty Pound, and there remains one hundred Pound for the Quantity of Blood in a Man weighing one hundred ſixty Pound.

ESSAY II.

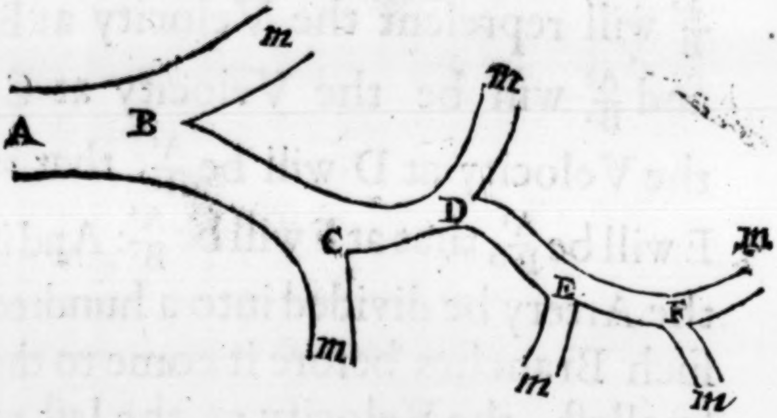
Of the Velocity of the Blood.

ALL who have wrote of the Velocity of the Blood ſince the Diſcovery of its Circulation by the immortal Dr. *Harvey*, have contented themſelves only to calculate the Quantity, which paſſes through the the Heart in ſome determined time: But none has as yet given us the abſolute Velocity with which it is thrown out of the Heart, runs through the *Aorta*, or any of its Branches. Many have indeed ſpoke of the rapid Motion of the Blood, and that it muſt be much greater near the Heart, than in the Extremities; but how much greater it is in that than in theſe, or whether it moves through the *Aorta*, at the rate of 5, 10, 100, or 1000 Feet in a Minute, is what has never as yet been determined; tho' next to the Circulation of the Blood its ſelf, it ſeems to be a thing of the greateſt Moment for explaining of the animal Oeconomy. After the Motion of the Blood was once determined, methinks it was but natural to have enquired in the next place with what Degree of Velocity it mov'd.

The Velocity of the Blood in the *Aorta* may be thus determined.

The Velocity with which a Fluid flows out of any Orifice uniformly ly and always running in the ſame Quantity, is equal to the Velocity of a Body which deſcribes a Space of the ſame length with that of a Cylinder, whoſe Baſe is equal to the Orifice, and whoſe Magnitude is equal to the Quantity of the Fluid that runs out in the ſame time, as 'tis evidently ſhewn in the *Lectiones Phyſicæ Jo. Keil*, *pag.* 114. Now ſuppoſe the Heart contracts eighty times in a Minute, and that each Contraction throws into the *Aorta* one Ounce of Blood. An Ounce of Blood is equal in bulk to 1.659 inch, and conſequently 80 Ounces are 132.72 inches. The Diameter of the *Aorta* in a middle ſiz'd Man, I have found to be 0.73 parts of an inch, and therefore its Orifice is 0.4187, by which divide 132.72, the Quotient 316 inches or 26 feet gives the length of the Cylinder, or the Space through which the Blood will go in a Minute, ſuppoſing it were conſtantly going out of the Heart with the ſame Velocity: But becauſe of the *Diaſtole* of the Heart, which is at leaſt two thirds of the time of a Pulſation, there goes out 80 Ounces in a third of a Minute, and conſequently the Velocity of the Blood is at leaſt thrice as great, or ſuch as will make it to move at the rate of 78 feet in a Minute; I have ſuppoſed that the Quantity of Blood that the Heart throws out every *Syſtole* is only one Ounce; becauſe that (being allowed of by all) gives the leaſt Velocity, and we are ſure it is at leaſt ſo much; bnt if every *Syſtole* throws out two Ounces, as many do ſuppoſe, then the Velocity is double to what it has been here determined, or the Blood moves at the rate of 156 feet in a Minute.

If the Sum of the Sections of the Branches of the Arteries were always equal to the Section of their Trunks, and if the Circuits in which the Blood moves were every where equal, the Velocity of the Blood would be every where the ſame it has been determined to be in the *Aorta*. But we find that the Sum of the Sections of the Branches do every where exceed the Section of their Trunks, and therefore the Velocity of the Blood muſt decreaſe upon this account, as the Number of Branches increaſe. Now let us ſuppoſe that the Sum of the Sections of the Branches, bears every where the ſame Proportion to their Trunks, and ſuppoſe A the Trunk of an Artery, and that at B it divides into two Branches, and the Branch B likewiſe into two at C, and that again into two at D, and ſo on: call A the Section of the Artery,



Artery, the Sum of the Sections of Branches at B call B, and thoſe at C let them be named C, and thoſe at D E, and F, call alſo D, E and F reſpectively. Let the Section of the Canal or Branch B C, be to the Section of the two Branches at C, as A is to B. Likewiſe the Section of the Canal C D to the Section of the two Branches at D, as A to B, *&c.* Then the Velocity at A, will be to the Velocity at B, as B is to A, and the Velocity at B, will be to the Velocity at C as B is to A, and the Velocity at C, will be to the Velocity at D, as B is to A, *&c.* Let A repreſent the Velocity at A, then

$\frac{A^2}{B}$ will repreſent the Velocity at B, and $\frac{A^3}{B^2}$ will be the Velocity at C, the Velocity at D will be $\frac{A^4}{B^3}$, that at E will be $\frac{A^5}{B^4}$, that at F will be $\frac{A^6}{B^5}$: And if the Artery be divided into a hundred ſuch Branches before it come to the ſmalleſt, the Velocity at the laſt of them will be $\frac{A^{101}}{B^{100}}$, if into a thouſand the Velocity at the laſt of theſe will be $\frac{A^{1001}}{B^{1000}} = A \times \frac{A^{1000}}{B^{1000}} =$ to the thouſandth part of $\frac{A}{B}$ multiplied by A: The Velocity therefore at A, is to the Velocity after a thouſand branchings, as A is to $A \times \frac{A^{1000}}{B^{1000}}$, that is as 1 to $\frac{A^{1000}}{B^{1000}}$, or as 1 is to the thouſandth Power of $\frac{A}{B}$.

Thus if the *Ratio* of A to B was known, the Velocity of the Blood at the ſeveral branchings of the Arteries might eaſily be determined; but this is only to be found by meaſuring of the Arteries; and by the Meaſures I have nicely taken from the Artery of the Thigh injected with Wax by Mr. *Cowper*, I find the following Proportions.

Trunks	Branches	Branches	Branches
50625	44521	35344	
35344	15129	24649	
24649	22500	11236	5041
22500	10404	21316	
21316	18496	8836	
18496	11449	7056	2500
11449	8464	5776	
44521	9025	38809	
32761	3364	2116	31684
31684	5776	29584	
29584		26896	
26896	7396	27889	
7396	7056	3600	
7056	3844	4624	
38809	3600	29929	
29929	7744	7744	29241
29241	2809	1764	27225
21316	13689	12321	95691
5184	4096	4096	
4096	3600	3600	
3600	3969	4225	
4225	3025	3136	
507067	209956	314546	

By theſe Numbers it appears, that tho' the *Ratio* is not everywhere exactly the ſame, yet the difference is generally inconſiderable, and we may without any notable Error take the *Ratio* of the Trunks to the Branches to be as the Sum of theſe Trunks to the Sum of their Branches, which is as 500677 to 620193, or as 10000 to 12387, and then $\frac{A}{B}$ is 0.80729, whoſe Logarithm is 9.9070296. This Logarithm multiplied by 30, gives the Logarithm of the 30th Power of 0.80729, which is 7.2108880, to which the Number anſwering in the Tables is 0.00162512; that is, the Velocity at A in any Artery is to the Velocity at its 30th branching as 1 to 0.00162512, or as 100000000 to 162512, or as 615 to 1. The Logarithm of 0.80729 multiplied by 40 gives for the Logarithm of the Velocity at the 40th branching 6.2811840, to which the Number anſwering in the Tables is 0.000191066. Hence the Velocity of the Blood in the *Aorta* is to the Velocity at the 40th diviſion as 1 to 0.000191066, or as 1000000000 to 191066, or as 5233 to 1. But if we ſuppoſe 50 ſeries of diviſions between the *Aorta* and ſome of the ſmalleſt Capillarys or evaneſcent Arteries, the Logarithm 9.9070296 multiplied by 50 gives 5.3514800, whoſeNumber is 0.000022463, and conſequently the Velocity of the Blood at the Heart will be to theVelocity in the laſt evaneſcent Artery, as 1 to0.000022463, or as1000000000 to 22463, or as 44507 to 1.

Thus having ſhewn how theVelocity of the Blood may be determined at each branching of the Artery, our next Enquiry muſt be to find out how many times an Artery may divide before it becomes the ſmalleſt Capillary, which may be thus done.

Suppoſe the *Ratio* of the Trunk to the Branches to be as $r : s$, and call the Trunk c, then $r : s : : c : \frac{sc}{r}$ which is therefore the Sum of the two firſt Branches, and each Branch is $\frac{s^2c}{4r^2}$. Again $r : s : : \frac{s^2c}{4r^2} : \frac{s^2c}{4r^2}$. This is the Sum of the ſecond branching, of which $\frac{1}{2}$ is the Branch $= \frac{s^2c}{4r^2}$; and juſt ſo the third Branch will be $= \frac{s^3c}{8r^3} =$ to the Cube of $\frac{s}{2r}$ multiplied by c.

Now if we call the Number of branchings x, and $\frac{s}{2r} = d$, the laſt Branch will be $d^x c$. Let us ſuppoſe the ſmalleſt Artery has its Diameter $\frac{1}{100}$ part of a Hairs Breadth, and that the Diameter of a Hair is the $\frac{1}{200}$ part of an Inch, the Section of this Artery will be 0.000 000 00 25, which I ſhall call $= e$. Then we have this Equation $d^x c = e$, which expreſſed by Logarithms is $x \times \text{Log.}\ d - 100\ x \times 100 = e + 100 - \text{Log.}\ c$ (for the Log. of the x power of d, is $x \times \text{Log.}\ d - \overline{x-1} \times \text{Log.}$ of Unity, or 100.) Hence $x = \frac{\text{Log.}\ e - \text{Log.}\ c}{\text{Log.}\ d - 100}$.

Now the *Ratio* between the Trunk and the Branches being as 10000 to 12387 : : $r : s$, the Logarithm of s divided by $2\ r$ is 9.7919361 Logarithm of d. The Logarithm of e is -8.6020600, and ſuppoſing c equal to the Diameter of the *Aorta* equal to 0.5329 decimals of an Inch, its Log. is -0.2733543, and the Logarithm of e *minus* the Logarithm of c is -8.3287057; this divided by the Log. $d - 100$, which is -0.2080639, gives in the Quotient 40, for the Number of diviſions between the greateſt and the ſmalleſt Artery; and conſequently the greateſt Velocity of the Blood will be to the leaſt, in the Proportion of 5233 to 1, or the Blood will move 5233 times ſlower in ſome of the Capillary Arteries than in the *Aorta*. Thus whilſt the Blood in the remoteſt diviſion of the Arteries moves one Foot, that in the *Aorta* moves 5233; now the Blood in the *Aorta* moving at the rate of 73 Feet in a Minute would run 5233 Feet in one Hour and ſeven Minutes; and therefore where the Blood moves the ſloweſt in the Arteries, its Motion is at the rate of a Foot in one Hour and ſeven Minutes.

As between the greateſt and the leaſt Velocity we are to conceive all the intermediate Degraes; ſo we are not to imagine that in every evaneſcent Artery there is the leaſt Velocity, but only in ſuch as have at leaſt 40 diviſions between them and the great Artery; and the Velocity of the Blood in the evaneſcent

vaneſcent Arteries is every where proportionable to the number of diviſions between them and the great Artery; and therefore in all the ſmall Arteries which come immediately from the *Aorta*, and which after a few diviſions tranſmit their Fluid to the Veins, the Velocity of the Blood is but a little diminiſhed.

From all this it appears that when the whole Maſs of Blood is to be altered, that the Courſe of Phyſick ought to be continued for a long Space of time, being the Blood moves ſlower and ſlower the farther it moves from a great Artery, and conſequently it muſt be a great time before the whole Maſs of Blood can be mixt with the alterative Medicine. And being the Circulation of the Blood through Glands which receive Arteries immediately from a great Veſſel, is very quick, they may carry off a great Proportion of the Medicine in a very little time, and therefore it is not the taking of great Quantities, but a conſtant taking that can alter the Maſs of Blood; and from hence it follows that when the Blood is to be altered by mineral Waters, which are apt to paſs through the Glands of the Kidneys, that they ought not to be drunk in large Quantities: For if they paſs off, they have not the deſigned Effect; and if they do not, being drunk in a little time, they mix but with a ſmall Quantity of Blood, which muſt diſorder the animal Oeconomy.

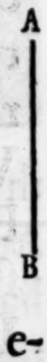
ESSAY

ESSAY VI.

Of the Force of the Heart in driving the Blood through the whole Body.

THere is not any Problem in the animal Oeconomy, which appears to be of greater difficulty than that about the force of the Heart. And the Labour and Pains *Borelli* has taken in 11 Propoſitions to determine it, do only demonſtrate that the method he uſed was extremely intricate, and his determination of its being equal to more than 135000 *lib.* weight is paſt all credibility. So much Geometry employed to ſo little purpoſe, by ſo great a Man, has undoubtedly deterred others from attempting it. But I hope to make it appear that a very little Geometry, rightly made uſe of, will eaſily determine this ſeemingly very intricate Problem.

If we have the Velocity wherewith a Fluid flows out at any Orifice without any reſiſtance from an anterior Fluid, it is eaſy to determine the force which produces that Motion. For let the Line A B be the Height from which if a Body fall, it will acquire a Velocity equal to the Velocity wherewith the Fluid flows out from the Orifice; then is the force which produces this Motion of the Fluid equal to the Weight of a Cylinder of the



the ſame Fluid, whoſe Baſe is equal to the Orifice, and whoſe Height is equal to 2 A B, by the 2d. Corol. of 36 Prop. of the 2d. Book of *Newton's Principia*.

Now the Blood flowing out of the Heart, is much reſiſted in its Motion by the anterior Blood in the Arteries and Veins, and therefore cannot flow with all the Velocity the force of the Heart would give it, were there no ſuch reſiſtance, ſome part of that force being ſpent in overcoming the reſiſtance which ariſes from the reſt of the Maſs of Blood. If therefore we could know how much the Velocity of the Blood is diminiſhed by this reſiſtance, or what Proportion the Velocity of Blood reſiſted, has to the Blood that is driven out, and not reſiſted; having already determined the Velocity of the Blood as it is reſiſted, we might eaſily from thence collect the Velocity by which the Blood would flow were it not reſiſted; and from thence the abſolute Force of the Heart. To find out this, I made the following Experiment; for to proceed entirely upon Speculation in ſolving of any *Phænomenon* of Nature, is certainly wrong, but an Obſervation or Experiment carefully made and duly applied, eaſes us of a great deal of trouble and leads us with greater Certainty to the Solution we want to know.

Having uncovered the *Iliack* Artery and Vein in the Thigh of a Dog near to his Body, and having paſſed convenient Ligatures under them, I opened the Vein the whole Diameter of the Veſſel, and received into a Cup all the Blood which run from it for the Space of ten ſeconds of a Minute; after that, I did the ſame by the Artery for the ſame ſpace of time, and had both the Quantities of Blood carefully weighed. There is no Experiment how eaſy ſoever, but what is attended with Circumſtances, of which one is not always aware, eſpecially at the firſt tryal, and which may very much alter the ſucceſs of the Experiment, and therefore I had this Experiment repeated ſeveral times, and did find by them, that the Quantity of Blood which run from the Artery was to the Quantity which run from the Vein, in the ſame Space of time, nearly as $7\frac{1}{4}$ to 3. Now the Velocity of the Blood in the *Iliack* Artery ſo near to the *Aorta*, is nearly the ſame with that in the *Aorta*, and conſequently the Velocity with which it flows out of the *Iliack* Artery cut aſunder, is the ſame with which it would flow out of the Heart unreſiſted, or the Blood runs through a Wound in the *Iliack* Artery with all the Velocity it receives from the Heart. Now all the Blood which runs along the *Iliack* Artery, returns again by the *Iliack* Vein; and conſequently the Quantities of Blood which paſs through both in the ſame ſpace of time are equal. The Quantity of Blood therefore which run out of the *Iliack* Vein cut aſunder, is the ſame which run through the *Iliack* Artery before it was cut, in the ſame ſpace of time. Having therefore the Quantity which runs through the *Iliack* Artery, when it is cut, and when it is not cut, we have their Velocities; for the Velocity of any Fluid running through the ſame Canal in equal ſpaces of time, is directly as the Quantities: But the Velocity of the Blood when the Artery is cut, is equal to that it receives by the full force of the Heart; and the Velocity, when it is not cut, is that Velocity with which the Blood moves through the *Aorta* reſiſted by the anterior Blood, and therefore theſe two Velocities are to one another as 7½ to 3.

Now if the Heart throws out 2 Ounces of Blood every *Syſtole* (as is moſt probable) then the Blood moves through the *Aorta* at the rate of 156 Feet in a Minute, as has been already computed; and therefore the abſolute Velocity wherewith the Blood would be forced into the *Aorta*, did it find no reſiſtance, is ſuch as would make it to move 390 Feet in a Minute, which is near 6½ Feet in a 2d of time. We muſt next enquire, what is the Height, from which if a Body falls, it will acquire this given Velocity; for this Height doubled gives the length of the Cylinder, whoſe Baſe is equal to the Orifice of the *Aorta*, and whoſe Weight it receives from the Heart. Now all the Blood which runs along the *Iliack* Artery, returns again by the *Iliack* Vein; and conſequently the Quantities of Blood which paſs through both in the ſame ſpace of time are equal. The Quantity of Blood therefore which run out of the *Iliack* Vein cut aſunder, is the ſame which run through the *Iliack* Artery before it was cut, in the ſame ſpace of time. Having therefore the Quantity which runs through the *Iliack* Artery, when it is cut, and when it is not cut, we have their Velocities; for the Velocity of any Fluid running through the ſame Canal in equal ſpaces of time, is directly as the Quantities: But the Velocity of the Blood when the Artery is cut, is equal to that it receives by the full force of the Heart; and the Velocity, when it is not cut, is that Velocity with which the Blood moves through the *Aorta* reſiſted by the anterior Blood, and therefore theſe two Velocities are to one another as 7½ to 3.

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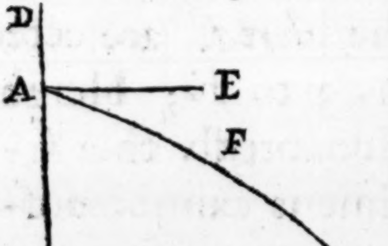
It is known by Experiment that the Force of Gravity, will make a Body move 30 Feet in a ſecond, which is the Velocity it acquires in falling through 15 Feet; and therefore this Velocity is to the Velocity of the Blood flowing without reſiſtance into the *Aorta*, as 30 to 6.5. But by the Doctrine of *Galileo*, the Heights from which Bodies acquire given Velocities, are as the Squares of the Velocities, that is as 900 to 42.25; therefore as 900 to 42.25 ſo is 15 to 0.74. This Height doubled gives the 1.48 or in Inches 17.76, which is the Height of a Cylinder of Blood, whoſe Baſe is equal to the *Aorta*, which we have ſuppoſed to be equal to 0.4187; and therefore the ſolid Content is 7.436112, the Weight of which is equal to the abſolute Force of the

Heart. This Weight is fiveOunces, and therefore the Force of the Heart s equal to the Weight of five Ounces.

Thus we ſee how vaſtly ſhort this Force falls of that determined by *Borelli*. The method and reaſonngs we have uſed are certainly juſt; all that can be objected is, that perhaps our Experiments upon which the demonſtration is founded were not ſo nice as they ought to have been, tho' they were repeated ſeveral times. But let us ſuppoſe the Veocities of the Blood reſiſted and not reſiſted in the *Aorta*, are not o one another as 3 to 7½; but as 3 to 15, and undoubtedly the Eror of the Experiment cannot poſibly be ſo great as to make ſo great a difference: Then if we calculate upon this *Ratio*, we ſhall find that the Force of the Heart is little above 16 Ounces.

But the Force of the Heart ma be found a ſtill more eaſy and ſimple way, thus. It is demonſtrate by the Writers of Mechanicks, tha if a Body whether fluid, or ſolid be projected from any Height, according to a horizontal Directio it will deſcribe by its Motion a *Parabola* whoſe *Latus Rectum*, is equa to four times the Height, fro which a Body muſt fall to acquir the Velocity wherewith it is at fir projected.



Having therefore opened the *liack* Artery of a Dog, laid in th horizontal Direction AE, and 1 inches high fro the Ground. found that th Blood moving i the *Parabola* A F C, touched th Ground at C, which was about Feet diſtant from the perpendicu-

la

lar A B let fall from the Heart. Now if A D be taken equal to $\frac{1}{4}$ of the *Latus Rectum* of the *Parabola*, it will be the Height from which the Blood muſt fall to acquire its Velocity at A. And becauſe from the Nature of a *Parabola*, the Rectangle under the *Latus Rectum*, and the Altitude A B is equal to the Square of B C; that is $4\,AD \times AB = Bcq$, or $AD \times AB = \frac{1}{4} Bcq$: therefore $AB : \frac{1}{2} BC :: \frac{1}{2} BC : AD$. that is 28 : 18 :: 18 : 11.5. $11\frac{1}{2}$ inches is therefore the Height the Blood muſt fall from to acquire the Velocity wherewith it is projected by the Heart. But this Height doubled gives the length of a Cylinder, whoſe Baſe is equal to the Orifice of the *Aorta*, and whoſe Weight is equal to the abſolute Force of the Heart: The length of the Cylinder is therefore 23 Inches. The Orifice of the *Aorta* of this Dog, I found to be .096 and therefore the ſolid Content of this Cylinder is 2.208, which is equal to one Ounce and the third part of an Ounce, equal to the Force of this Dog's Heart. Now the Heart of this Dog weighed two Ounces, and if we ſuppoſe the Strength of two Hearts to be to one another as their Weights, (which we reaſonably may, the Structure and Fabrick in both being alike) and that the Weight of an ordinary humane Heart is 12 Ounces, then he Force of ſuch a Heart, will be equal to almoſt 8 Ounces Weight. So that though this is ſomething more than what was determined before; yet it is very inconſiderable, and of no moment in reſpect of what the Force of the Heart was commonly imagined to be.

After this method the Force of the urinary Bladder may certainly ly be determined: For ſuppoſe the Bladder 3 Feet from the Ground, and that it throws out the Urine in a horizontal Direction 6 Feet: Then the Height from which it muſt fall to acquire the Velocity by which it is thrown out from the Bladder, will be 3 Feet, and this Height doubled is the Length of a Cylinder, whoſe Baſe is equal to a tranſverſe Section of the *Urethra*, (the Diameter of which Section I take to be about $\frac{3}{10}$ parts of an Inch) and whoſe Weight is the Force of the Bladder. Now the Weight of ſuch a Cylinder will be found to be near 3 Ounces, which is therefore the Force of the Bladder in throwing the Urine 6 Feet forwards.

Borelli required a Force in the Heart equal to the preſſure of 180000 *lib.* weight, to move 20 *lib.* weight of Blood, whereas from what has been demonſtrated, above 100 *lib.* weight of Blood may be moved by a Force in the Heart which does not exceed the preſſure of one Pound at moſt. This may to ſome ſeem very ſtrange at firſt ſight; but if we conſider the Caſe attentively, this Force in the Heart will be found ſufficient for all that is required of it. It is not indeed requiſite that the Force of the Heart ſhould be able to move 100 *lib.* of Blood at reſt; but this Blood being once moved, the Force of the Heart muſt be ſuch as will preſerve the Motion at firſt communicated to the Blood: How the Blood came firſt by its Motion, is not my preſent Enquiry, that I leave to be determined by the occult Philoſophers: However this is certain, that if the reſiſtance of the Blood bore always the ſame Proportion to the Force of the Heart that it does now, that the

Blood never could at firſt be put in Motion by the Heart. Now did the Blood conſtantly move forwards, with the Motion at firſt communicated to it, and did the Coats of the Veſſels make no reſiſtance, the poſterior Blood would not be retarded by the anterior, and the Motion of the Blood would equal the intire Force of the Mover. But becauſe of the reſiſtance made by the Coats of the Blood-Veſſels, and the Force which is ſpent in diſtending of them, the Blood is conſtantly retarded in its Motion as it circulates, and would in a ſhort time ſtop, were not the Motion loſt made up by a freſh impulſe from the Heart; and therefore the Force of the Heart muſt be equal to the reſiſtances the Blood meets with in its Motion; if it were more, the Velocity of the Blood would be continually encreaſing;

if leſs, it would continually decreaſe, and at laſt ſtop. And from hence it is evident, that if the Circulation of the Blood were once ſtopt, all the Force of the Heart could never ſet it a moving again.

ESSAY IV.

OF

Animal Secretion.

IN explaining the Manner, how the ſeveral Fluids of the Animal Body are ſeparated from the Blood, I ſhall ſhew,

Firſt, *How they are formed in the Blood, before they come to the place appointed for Secretion.* And,

Secondly, *I ſhall demonſtrate in what manner they are ſeparated from the Blood by the Glands.*

The Blood conſiſts of attracting Particles.

The Blood of all Animals, when drawn out of the Body, does naturally, and of it ſelf, divide into two different parts: Of which the Red does in a little time coagulate, but the Serum remains fluid. If we view a drop of Blood with a Microſcope, we diſcern a number of Red Globules ſwimming in a limpid Fluid; and perceive how the Globules, attracting one another, unite like Spheres of Quickſilver, which, as they touch, run into one another: And conſequently the Blood divides into two parts.

The Serum conſiſts of attracting Particles.

After the Coagulation of the Red Globules of the Blood, if we examine the Serum with a Microſcope, we find in it likewiſe a great number of Corpuſcles of various Figures and Magnitudes, ſwimming in a limpid Fluid. Theſe do not attract and unite with one another as the former did, till ſome part of the Fluid, in which they ſwim, has been evaporated by Heat; and then they likewiſe attract one another, and form a Coa Coagulum, as the Globules did.

This therefore is matter of fact, that the Blood conſiſts of a ſimple and limpid Fuid, in which ſwim Corpuſcles of various Figures and Magnitudes, and endued with different Degrees of an attractive force. Now of ſuch Particles, as the Blood conſiſts of, muſt the Fluids be compoſed, which are drawn from it; and as in the Blood the Particles attract one another, and cohere together, ſo likewiſe may the Particles of the Fluids which are ſeparated from it

Moſt Fluids conſiſt of attracting Particles.

Moſt of the Liquors we know are form'd by the Coheſion of Particles of different Figures, Magnitudes, Gravities, and attractive Powers, ſwimming in an aqueous Fluid, which ſeems to be the common Baſis of all. Why are there ſo many ſorts of Water, differing from one another in Properties? Is it not, becauſe of the Corpuſcles of Salts and Minerals with which the Element is impregnated? What elſe is Wine, but Water impregnated with the Particles of the Grape, and Ale with Particles of Barley? Are not all Spirits the ſame Fluid ſaturated with ſaline or ſulphureous Particles? And all Liquors are more or leſs fluid, according to the greater or ſmaller Coheſion of the Particles, which ſwim in this aqueous Fluid; and there is hardly any Fluid without this Coheſion of Particles, as is apparent by the Bubbles which ſtand upon the Surface of Water, Wine, and even of ſome Spirits.

The Secretions conſiſt of attracting Particles.

But that ſome of the Fluids, which are ſecerned by the Glands from the Blood, are actually compoſed by the Coheſion of ſeveral ſorts of Particles, is very evident. We know that in Milk there are three or four ſeveral ſorts of Subſtances, and yet when it is examined by the Microſcope it appears, like Blood, to conſiſt of very ſmall Globules, ſwimming in a limpid Fluid. Urine has the ſame Appearance, and contains perhaps more Principles: And there is no doubt but that Tears, Spittle, and Sweat are all compounded Liquors. If ſome of the Fluids which are ſecreted by the Glands are not eaſily reſolved into their compounding Parts; we can no more conclude from thence, that they are not compounded, than we can that the Blood is not, becauſe it does not ſeparate into about thirty different Fluids, which are conſtantly extracted from it by the Glands.

The Reaſon why it is not evident in all.

If the Particles, which attract one another, are ſtill more powerfully attracted by the Particles of the Fluid in which they ſwim, than by one another, they can never of themſelves ſeparate from the Fluid; and this is the caſe of all Salts diſſolv'd in a large Quantity of Water, and of Urine, when it neither breaks nor ſettles. But if the Particles, which ſwim in the Fluid, are more ſtrongly attracted by one another, than they are by the Fluid in which they ſwim, then this Fluid muſt neceſſarily go into parts; and the Corpuſcles uniting, will either ſink, ſwim, or aſcend in the Fluid, according to their ſpecifick Gravities; unleſs there ſhould be ſo many interſtices within the coagulated Maſs, as will receive the greateſt part of the Fluid. From hence it is plain that the red part of the Blood conſiſts of Particles which attract one another, more than they do the watry Fluid, in which they ſwim; and that the other Particles which are in the watry Fluid of the Serum, are more attracted by it, than by one another. But if part of this watry Fluid be evaporated, by which means the Particles attracting approaching nearer, the Force of their Attraction is increaſed, and they unite; and conſequently this force muſt be much ſtronger in Particles that are very nigh one another, than when they are at a diſtance.

This Attraction is an univerſal Power in Matter.

This Power by which the Particles of the Blood attract one another is the ſame with that which is the Cauſe of the Coheſion of the Parts of Matter, and was firſt communicated to me by my Brother at *Oxford*, above ſeven Years ago; who had no ſooner diſcovered it, but he deduced from it the Coheſion of the parts of Matter, the Cauſe of the Elaſticity of Bodies, of Fermentations, Diſſolutions, Coagulations, and many other of the Operations in Chymiſtry. And ſince it will appear, that the whole Animal Oeconomy does likewiſe depend upon this attractive Power; it ſeems to be the only Principle from which there can be a ſatisfactory Solution given of the *Phænomena* produc'd by the *Minima Naturæ*; as that other attractive Principle, which is of a different kind from this, and was firſt diſcovered by the incomparable Sir *Iſaac Newton*, demonſtratively explains the Motions of the great Bodies of the Univerſe; which is not in the leaſt diſturb'd by the attracting Power we now ſpeak of, which only exerts it ſelf in Particles that are at a ſmall diſtance from one another. Now, that there is ſuch an attractive Power in Nature as this we have mentioned, I think, can be denied by none, that duly conſider the Experiments and Reaſons given for it by Sir *Iſaac Newton*, in the Queſtions annexed to the Latin Edition of his Opticks.

From this Principle that the Blood conſiſts of Corpuſcles of various Figures

gures and Magnitudes, and endued with various Degrees of an attractive Power, and that of ſuch Particles the Fluids ſecerned by the Glands are compoſed; I ſay, from this Principle (for which we have ocular Demonſtration) I ſhall endeavour to ſhew how the Corpuſcles that compoſe the Secretions are formed in the Blood, before they arrive at their ſecerning Glands, having firſt laid down the following Propoſitions, being only ſo many of the Laws of Attraction as at preſent we have occaſion for; the reſt being contained in my Brother's Theorems publiſhed in the *Philoſophical Tranſactions*.

Some Laws of Attraction in ſmall Particles of Matter.

Prop. I. *There is a Power in Nature by which each Particle of Matter attracts every other Particle, with a Force that increaſeth in a greater Proportion than that, by which the Squares of the diſtance decreaſe,* viz.

in a reciprocal triplicate, or quadruplicate Proportion to the diſtances.

For were the Particles that compoſe the attracting Body endued with a Power that attracted only with a Force reciprocal to the Squares of the Diſtances, the Attraction would not be much ſtronger at the Contact than at ſome determined Diſtances from it: As is evident in the Caſe of Gravity, which ariſes from a Power of attracting reciprocally as the Squares of the Diſtances; Bodies being of the ſame Weight, when they touch the Earth, as they are at an hundred Feet diſtance. But by all Experiments, this Power is much greater at the Contact, or extremely near it, than at any determined Diſtance. The Particles of Salt diſſolved in a large quantity of Water, do not ſenſibly attract one another, till part of the Water has been evaporated; by which means approaching each other, their attractive Force increaſes, they run to one another, and uniting form Cryſtalls, whoſe Parts have a ſtrong Coheſion. And therefore the Force, by which each Particle attracts every other Particle, muſt increaſe in a much greater Proportion, than that by which the Squares of the Diſtances decreaſe.

Prop. II. *The attractive Force is* cæteris paribus *proportional to the Solidity of the Particles.*

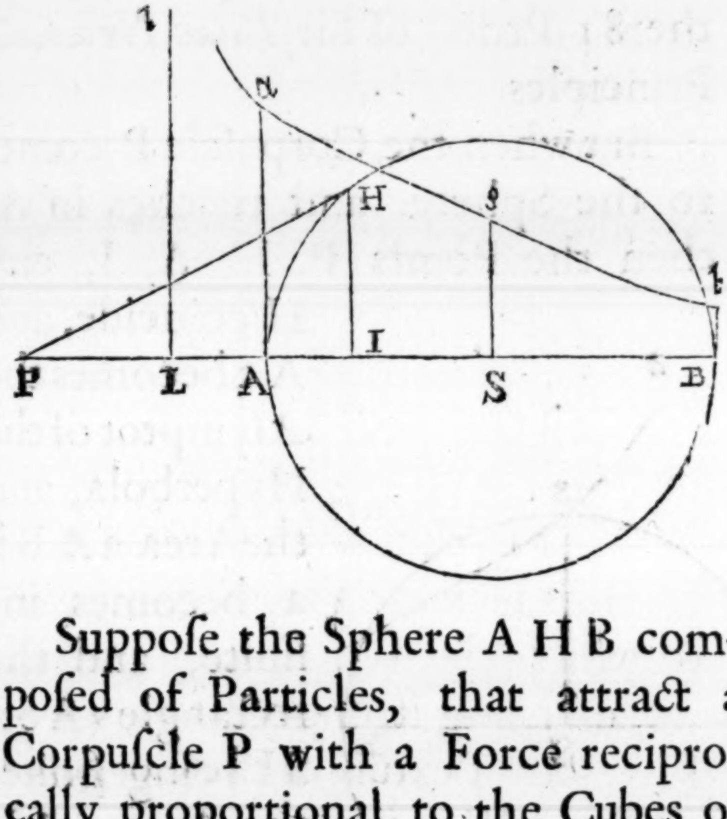
The attractive force of a Particle is compoſed of the Sum of all the Attractions of the Parts of that Particle: Now theſe Parts are moſt numerous in the moſt ſolid Particles, and therefore *cæteris paribus*, their attractive Force is ſtrongeſt.

Schol. This Propoſition is to be underſtood of the ſmalleſt Particles of Matter, and not of the Corpuſcles made up of thoſe Particles. For

Corpuſcles may be ſo compounded, that the moſt ſolid and compact Particles may make up the lighteſt Corpuſcles, if the interſtices between the Particles be large, ſo that few of them may be diffuſed thro' a great Space: Such a Corpuſcle, tho' it conſiſts of Particles that are endued with a ſtrong attractive Power, may yet be ſpecifically lighter than another, which conſiſts of Particles not ſo ſolid, but cloſer together. And ſuch ſort of Corpuſcles I conceive all Salts to be, whoſe Particles of the laſt Compoſition are very ſolid, but that there are great Interſtices between thoſe Particles, into which the Water ruſhing with a force, being ſtrongly attracted, diſſolves the Texture of the Corpuſcles.

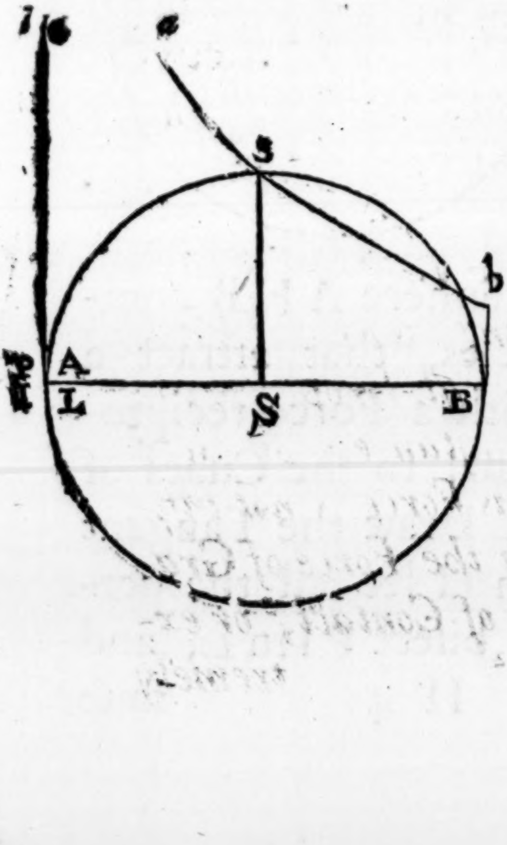
Prop. III. *If Particles of Matter attract each other with a Force, that is in a reciprocal triplicate, or a greater Proportion of their Diſtances, the*

the Force by which a Corpuſcle is drawn to a Body made up of ſuch attractive Particles, is infinitely greater at the Contact, or extremely near it, than at any determined Diſtance from it.



Suppoſe the Sphere A H B compoſed of Particles, that attract a Corpuſcle P with a Force reciprocally proportional to the Cubes of their Diſtances. Draw the Tangent P H, and from H let fall the perpendicular H I, biſect P I in L, and raiſe the Perpendiculars L l, A a, S s, B b, and make S s = to S I: with the Aſymptots L B, L l thro' b s, deſcribe the Hyperbola b s a, and the Area a A B b — the rectangle 2 A S x S I will repreſent the Attraction of the Corpuſcle P by the 81 Prop. of Sir *Iſaac Newton*'s Principles.

But when the Corpuſcle P comes to the Sphere, and touches in A, then the Points P, L, A, I, and H, coincide, and A a becomes the Aſymptot of the Hyperbola, and the Area a A B b a becomes infinite, and the rectangle 2 A S x S I being finite, the Area a A B b a — 2 A S x S I will be infinite



nite; and conſequently the Force, by which the Corpuſcle P is attracted by the Sphere, will be likewiſe infinite.

If the Sphere conſiſts of Particles that attract in a reciprocal quadruplicate Proportion of their diſtances, the Force by which a Corpuſcle will be drawn to the Sphere will be as $\frac{1}{PS^2 \times PI}$. Now when the Corpuſcle comes to touch the Sphere, P I becomes $=0$, and conſequently whatever is divided by it, becomes infinite, and therefore the attractive Force of the Sphere, at the Contact being proportional to $\frac{1}{PS^2 \times PI}$ will be infinite.

Prop. IV. *If a Body conſiſts of Particles attracting with a Force that is in a reciprocal Proportion to the Cubes of the diſtances, or in a greater; and if this Force is not infinitely greater than the Force of Gravity at the Point of Contact, or ex-*

tremely near it, at any determined diſtance from the Point of Contact, it muſt be infinitely leſs than the Force of Gravity.

This is clear by the laſt Propoſition: Or in that Caſe the Force of Attraction in a Corpuſcle removed from the Contact is infinitely leſs than at the Contact, or extremely near it; but at the Contact it is not infinitely greater than the Force of Gravity by Suppoſition: Therefore the Force, by which a Particle removed at a determined diſtance from the attracting Body is attracted, is infinitely leſs than the Force of Gravity.

Prop. V. *The Force, by which the Particles of Matter attract each other, when extremely near the Contact, is not infinitely greater than the Force of Gravity.*

This is evident: Becauſe in the ſtrongeſt coheſion of Particles touching

ing one another, we find that the Weight of ſome Bodies will pull the Particles aſunder, tho' that Body may be prodigiouſly greater and heavier than the Particles united. Sir *Iſaac Newton* calculates from the Inflection of the Rays of Light, that this Force near the Contact is 10000 0000 0000 0000 greater than the Force of Gravity.

Corol. Particles removed at a determined diſtance from the Body attracting, are not acted upon by it; becauſe this Force muſt then vaniſh, or, which is the ſame thing, be infinitely leſs than the Force of Gravity.

Prop. VI. *A large Particle attracts not more ſtrongly than a ſmall one of the ſame Solidity, but a Diverſity of Figures cauſes different Degrees of Attraction in Particles that are otherwiſe the ſame.*

This attractive Power acts only on ſuch Particles as are extremely near; and therefore of a large Particle, the remoteſt parts conduce nothing to Attraction: And for the ſame Reaſon the attractive Force varies, according as the Particles are Cones, Cylinders, Cubes, or Spheres, and *cæteris paribus* a Spherical Particle, has the ſtrongeſt attractive Power.

Prop. VII. *If Particles ſwimming in a Fluid, attract one another more ſtrongly, than they do the Particles of the Fluid, the Force by which they come to each other, will be that by which their attractive Force exceeds the attracting Force of the Fluid.*

For the Particles of the Fluid, that lie directly between the attracting Particles, being more preſſed than the other ambient Particles; they will from the Nature of Fluidity, with that exceſs of Preſſure, drive the other Particles out of their places, and make way for the attracting Particles to come together.

Prop. VIII. *If Particles ſwimming in a Fluid, are more attracted by the Fluid, than by one another, they will recede from one another, with a Force that will be equal to the difference of their mutual Attraction, and the Attraction of the Fluid.*

For the ambient Particles of the Fluid attracting more ſtrongly, will with their exceſs of Force draw the other Particles to themſelves, and make them to recede from one another.

Prop. IX. *The Force, by which Particles attracting one another cohere, is greater* cæteris paribus, *where the Contact is greater.*

For the parts that are farther remov'd from the Contact, conduce nothing to the Force of the Coheſion; and a greater Power muſt be requiſite to ſeparate two Particles, which cohere in two points, than two Particles which cohere only in one point, if the Degree of Coheſion be equal in each point. Thus two poliſhed Marble-ſtones (ſuppoſe a Foot ſquare) adhere more ſtrongly than any other two Bodies of a Foot ſquare, which are not ſo ſolid but have more Pores and Interſtices between their parts,. and which will not receive ſo good a poliſh, by which the parts come to a cloſe Contact with one another.

Prop. X. *If the attracting Corpuſcles are elaſtick, they muſt neceſſarily produce an inteſtine Motion, greater or leſſer, according to the Degrees of their Elaſticity and attractive Forces.*

For after meeting they will fly from one another with the ſame Degree of Velocity, (abating the reſiſtance of the Medium) that they met together with; but when they approach other Particles in their Reſilition, their Velocity muſt increaſe, becauſe they are afreſh attracted, and therefore meeting a ſecond time, they will recede with a greater Velocity than they did at their firſt Concurſion; and ſo their Velocities will be increas'd by every Concurſion and Reſilition, which muſt neceſſarily produce a ſenſible inteſtine Motion; and the ſtronger their attractive Force, and the greater their Elaſticity, their Concurſions and Reſilitions will be the more ſenſible.

Prop. XI. *Particles attracting one another in a Fluid, moving either with a ſwift or ſlow progreſſive Motion, attract one another juſt the ſame,*

ſame, as if the Fluid was at reſt, if all the Particles move equally; but an unequal Velocity of the Particles does mightily diſturb their Attractions.

The Particles do all by Hypotheſis move equally and conſtantly, the progreſſive Motion of the Fluid does not alter their Diſtances, that is to ſay, it does not repel them from one another; and conſequently they muſt attract one another with the ſame Facility, as if the Fluid was at reſt. But if ſome Particles move faſter than others, ſome muſt change their Poſition in reſpect to each other, and thoſe parts, which by the Force of Attraction would have come together, will by this unequal Motion be carried from one another. Thus Salts do not cryſtallize, nor the terreſtrial Particles of Urine attract one another, and unite, till the Water in which they are diſſolved, is almoſt cold; and the inteſtine Motion of its Particles, cauſed by Heat, is quieted.

Theſe are the Laws by which Secretions are firſt formed in the Blood, before they are ſeparated by the Glands. The Particles of the Blood returning by the Veins mutually attract one another, and cohering form Globules too big for any Secretion; and therefore there was an abſolute neceſſity that they ſhould be broken and divided in the Lungs by the Force of Reſpiration: Which becauſe it is commonly thought to be inconſiderable, by reaſon we are not ſenſible of it, I ſhall therefore here make an Eſtimate of it.

The Force of the Air upon the Blood in breathing determined.

It is a known Experiment, that by blowing into a Bladder we can raiſe by the Force of our Breath a conſiderable Weight: Having therefore got an oblong Lamb's Bladder;

which being tied at both ends was nearly of a Cylindrical Figure, I fixt a Pipe into one end, and tied a Weight to the other; I then faſtned the Pipe at ſuch a diſtance from the Ground, as juſt allowed the Weight to reſt upon the Ground. The Bladder being thus fixt, I found that by the force of an eaſy Expiration, I could raiſe 7 *lib.* Weight and the greateſt Weight I could raiſe by the ſtrongeſt Expiration was 28 *lib.* Now the Force by which the Air entered the Pipe was that Force by which it was drove out of the Lungs: If therefore we can determine the Force by which the Air entered the Pipe, we have the Force by which it was drove through the *Aſpera Arteria.*

But the preſſure of the Air upon the Bladder is equal to twice the Weight it can raiſe, becauſe the upper part of the Bladder, being fixt, reſiſts the Force of the Air, juſt as much as the Weight at the other end: And again, ſince the Air preſſes every way equally, the whole preſſure will be to that part of it which preſſes on the Orifice of the Pipe, as the whole Surface of the Bladder is to the Orifice of the Pipe; that is, as the Surface of a Cylinder, whoſe Diameter was 4 Inches and Axis 7, is to the Orifice of the Pipe. The Diameter of the Pipe was 0.28, and therefore its Orifice was 0.616; the Surface of the Cylinder was 88: Therefore as 88 : 0.616 :: 14, double the leaſt Weight raiſed, to 0.098, which is almoſt two Ounces, and in raiſing of the greateſt Weight it is near 7 Ounces. Theſe therefore are the Forces by which the Air is drove thro' the *Aſpera Arteria* in an eaſy and a ſtrong Expiration. Now if we conſider the Lungs as a Bladder, and the *Larynx* as a Pipe, the Preſſure upon the Orifice of the *Aſpera Arteria* when the Air is drove out, is to the Preſſure upon the Lungs, as the whole Surface of the Lungs is to the Orifice of the *Aſpera Arteria.* Let us ſuppoſe the Diameter of the *Larynx* to be 5, (which is more than it can be) then the Orifice of the *Larynx* is 0.19. Let us ſuppoſe the two Lobes of the Lungs to be two Bladders or Spheres, whoſe Diameters are each 6 Inches, their Surfaces are 113 Inches each, and the Preſſure upon the *Larynx* will be to the Preſſure upon the whole external Surface as 0.19 to 226, which is as 1 to 1189; and therefore if the Preſſure upon the *Larynx* in an ordinary breathing is 2 Ounces, the Preſſure upon the whole external Surface of the Lungs is 148 *lib*; and the utmoſt Force, when the Preſſure upon the *Larynx* is 7 Ounces, will be equal to 520 *lib.* weight: But the Lungs are not like an empty Bladder, where the Air preſſes only upon the Surface; for they are full of Veſicles, upon the Surface of each of which the Air preſſes as it would upon the Surface of an empty Bladder; and therefore to know the whole Preſſure of the Air, we muſt determine the internal Surfaces of the Lungs. To do this, let us ſuppoſe that $\frac{1}{3}$ part of the Lungs is taken up with the Branches of the *Trachæa Arteria*, that another third Part the blood Veſſels fill, and the Remainder is Veſicles, where we ſuppoſe the chief Preſſure upon the blood Veſſels to be made. Now both Lobes of the Lungs contain 226 ſolid Inches, of which $\frac{1}{3}$ or 75 Inches are full of Veſicles. Let the Diameter of each Veſicle be $\frac{1}{50}$ part of an Inch, the Surface of a Veſicle will be .001256, and the Solidity 0000043, by which Sum if we divide 75, the Space filled by the Veſicles, the Quotient gives us 17441860, for the Number of Veſicles in both Lobes of the Lungs. This Number multiplyed by .001256 the Surface of a Veſicle, gives the Sum of the Surfaces of all the Veſicles, to wit, 21906.976 Inches. And therefore the Preſſure upon the *Larynx*, will be to the Preſſure upon the whole Surface of the Lungs, as 0.19 to 21906.976; and conſequently when in an ordinary Expiration the Preſſure upon the *Larynx* is 2 Ounces, the Preſſure upon the whole internal Surfaces of the Lungs will be 14412 *lib.* weight, and the utmoſt Force of the Air in breathing when the Preſſure upon the *Larynx* is 7 Ounces will be 50443 *lib.* weight. Tho' theſe ſeem to be prodigious Weights, yet it muſt ſtill be underſtood, that the Preſſure upon each Part of the Surface of the Lungs equal to the Orifice of the *Larynx*, is not greater than it is at the *Larynx*, and that theſe vaſt Weights ariſe from the vaſt extent of the Surfaces of the Veſicles, upon which it was neceſſary that the Blood ſhould be ſpread in the ſmalleſt capillary Veſſels; that each Globule of Blood might as it were immediately receive the whole Force and Energy of the Air, and by that be broke into ſmaller Parts fit for Secretion and Circulation. And from thence we may learn the mechanical Reaſon of the Structure of the Lungs: For being the whole Blood of the Body was to paſs thro' them, in order to receive the Virtue of the Air, and that could not be communicated but in ſmall capillary Veſſels, it was neceſſary that the Surfaces upon which they were to be ſpread, ſhould be proportioned to their Number, which is admirably well provided for by the wonderful Fabrick of the Lungs.

The effects of the different Gravities of the Air conſidered upon Aſthmatick People.

If the Gravity of the Air was always the ſame, and if the Diameter of the *Trachæa Arteria*, and the time of every Expiration were equal in all, this Weight upon the Lungs would be always the ſame. But ſince we find by the Barometer, that there is 3 Inches difference between the greateſt and the leaſt Gravity of the Air, which is a $\frac{1}{10}$ part of its greateſt Gravity; there muſt be likewiſe the difference of a tenth part of its Preſſure upon the Lungs at one time and another: for the *Momenta* of all Bodies, moved with the ſame Velocity, are as their Gravities. This is a difference, which ſuch as are Aſthmatick muſt be very ſenſible of, eſpecially if we conſider that they likewiſe breath thicker, that is, every Expiration is performed in leſs time; if in half the time, and the ſame Quantity of Air drawn in, then the Weight of the Air upon the Lungs muſt be 57648 *lib.* of which $\frac{1}{10}$ part is 5764 *lib.* and conſequently aſthmatick People upon the greateſt Riſe or Fall of the Barometer, feel a difference of the Air, equal to above $\frac{1}{3}$ of its Preſſure in ordinary breathing. Again, if the *Trachæa Arteria* is ſmall, and its Aperture narrow, the Preſſure of the Air increaſes in the ſame Proportion, as if the times of Expiration were ſhorter; and therefore a ſhrill Voice is always reckoned amongſt the prognoſtick Signs of a Conſumption, becauſe that proceeds from the narrowneſs of the *Larynx*, or *Trachæa Arteria*; and conſequently encreaſes the Preſſure of the Air upon the Lungs, which upon every Expiration beats the Veſſels ſo thin, that at laſt they break, aud a ſpitting of Blood brings on a Conſumption apace.

By this Preſſure of the Air, the Coheſions of the Globules of the Blood are diſſolved.

I ſuppoſe, no body doubts whether this Preſſure of the Air upon the Lungs in breathing be ſufficient to break the Globules of the Blood, and to diſſolve all the Coheſions they might contract in their Circulation thro' the Arteries and Veins. And when the Blood is thus diſſolved and thrown out by the Heart into the *Aorta*; it is evident that the reunion of the Particles requires more or leſs time, according to their ſeveral attractive Powers, even tho' they all moved with the ſame Velocity, and in the ſame Direction.

How the Union of the Particles is hindred near the Heart.

But neither doth this happen, for a Fluid moves thro' a Cylindrical or Conical Veſſel (ſuch as the Arteries are) with a greater Velocity at the *Axis* than at the Sides. And again, the Blood is thruſt into the *Aorta* by the whole Force of the Heart, and Fluids when they are preſſed preſs *undequaque*, by which means the Arteries are dilated, and the Blood moves not only forwards, but likewiſe preſſes perpendicularly on the Sides of the Arteries; and as the Sides of the Arteries (being Elaſtick) return, they preſs the Blood from them every way, which muſt produce an inteſtine Motion, and by the 11th Propoſition hinder the Attraction of the Particles, and by this frequent and ſtrong Colliſion of the Particles of the Blood againſt the Sides of the great Arteries, the Coheſions of the Particles, if any of them happen to unite, will be immediately diſſolved. Again, this inteſtine Motion muſt greatly encreaſe upon the account that many of the Particles of the Blood are elaſtick: For by this Reſiſtance of the Sides of the Veſſels, they muſt neceſſarily hit one againſt another, and being elaſtick, reflect from one another, and ſo increaſe the inteſtine Motion of the Blood by the 10th Propoſition. Upon this inteſtine Motion of the Blood depends its Heat, which therefore is every where proportional to the *Impetus* of the Particles againſt the Sides of the Veſſels, ſuppoſing the Elaſticity of the Particles every where the ſame. Now the *Impetus* of the Particles againſt the Sides of the Veſſels decreaſes, as the Sum of the Cavities of the Veſſels increaſes; and conſequently where the Sum of the Cavities of the Veſſels is greateſt, there the inteſtine Motion of the Blood is leaſt, and the attractive Power of the Particles *cæteris paribus* is greateſt.

By

The Effects of Steel.

By the by, we may obſerve how that Steel, being an elaſtick Body, heats the Blood more than any other Mineral; and how by its Elaſticity, the Force of its own Particles in removing Obſtructions, as well as thoſe of the Blood, increaſe; and therefore it is a better Deobſtruent, than ſome other Minerals, which have a greater Gravity.

What Particles unite firſt.

The Particles which unite firſt after the Blood is thrown out of the Heart into the great Artery, muſt be ſuch as have the ſtrongeſt attractive Force; and ſuch as have the leaſt, unite laſt; and all the intermediate ones according to their ſeveral Natures. The Particles endued with the ſtrongeſt attractive Powers, are by the 2d and 6th Propoſition, the moſt ſolid ſpherical Corpuſcles, and the Quantity of their Contact being the leaſt, by the ninth Propoſition, the Secretion which they compoſe muſt be the moſt fluid, and ſuch is the Liquor in the *Pericardium*.

The Reaſon of the Situation of the Kidneys.

The Salts are Corpuſcles that are ſtrongly attracted, and have a moſt cloſe Union with the Fluid of Water; for tho' the Lungs may divide the Particles of Salt from one another, yet ſtill they firmly adhere to the aqueous Humour in which they ſwim, and therefore they may likewiſe at firſt be drawn off: Upon which Account the Kidneys have their Situation ſo near to the Heart. And indeed they could not have been placed at a greater Diſtance, and have ſeparated ſuch a Quantity of Urine, as they now do, not only upon the Account of the great Quantities of Blood they receive where they are; but likewiſe, becauſe if they had a more diſtant Station, other Particles muſt have united with the Salts and aqueous

Particles (as in their preſent Station ſome terreſtrial Particles do) and conſequently the Urine could not have been diſtilled ſuch as it is now, or at leaſt but in a ſmall Quantity.

What Particles are longeſt in uniting.

The Corpuſcles, which are the ſloweſt in uniting, muſt be ſuch as have the weakeſt attractive Force, which by the 2^d and 6^th Propoſition, are ſuch as have the leaſt Solidity, and ſuch as have their Surfaces the moſt extended; and therefore Corpuſcles, which have plain Surfaces, are longer in uniting than ſpherical Corpuſcles, but when united, they cohere more ſtrongly by the 9^th Propoſition, and compoſe the moſt viſcid Fluids: And therefore the moſt viſcid Secretions, ſuch as the Mucilage of the Joints, are ſeparated at the greateſt Diſtance from the Heart, where the Sum of the Cavities of the Arteries is greateſt, the *Impetus* of the Blood againſt

gainſt the Sides of the Veſſels (which is always proportional to the Velocity of the Blood) ſmalleſt, and conſequently where the Particles move almoſt with an equal Velocity, and therefore the Attractions of the weakeſt are not diſturbed, by the 11th Propoſition.

The Gall which is ſecerned by the Liver, and the Seed by the Teſticles, do ſeem to be two conſiderable Objections againſt what has been ſaid. But I will make it appear that they are ſo far from proving any thing againſt this Doctrine of Secretions, that they are the greateſt Arguments that could poſſibly be urged for the truth of it. Nothing does more evidently demonſtrate the Intentions of Nature in her Operations than the various Methods ſhe is ſometimes forced to take to bring the ſame thing about.

This is moſt eminently remarkable in the Secretion of the Gall; which, being to be mixed with the Chyle as it comes out of the Stomach into the *Duodenum*; could no where be ſo conveniently ſecerned from the Blood, as where the Liver is placed. Now had all the Branches of the Celiack Artery carried all the Blood to the Liver, from which the Gall was to be ſeparated, it is evident, conſidering the Nearneſs of the Liver to the Heart, and the inteſtine Motion of the Blood, that ſo viſcid a Secretion, as the Gall is, could never have been formed in the Blood, and conſequently, could never have been ſecreted by any Gland in that Place. In this Caſe Nature is forced to alter her conſtant Method of ſending the Blood to all the Parts of the Body by the Arteries. Here ſhe forms a Vein (which is no

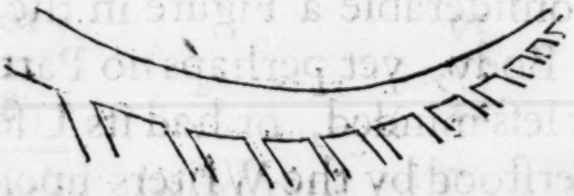
This Doctrine illuſtrated by the Separation of the Gall in the Liver.

Branch of the *Vena Cava*, as all the others are) and by it ſhe ſends the Blood from the Branches of the Meſenterick and Celiack Arteries (after it has paſſed thro' all the Inteſtines, Stomach, Spleen, Caul, and Pancreas) to the Liver. By this extraordinary Contrivance the Blood is brought a great way about, before it arrives at the Liver; and its Celerity is extremely diminiſhed, that all the Corpuſcles, which are to form the Gall, may have ſufficient time to attract one another, and unite before they come to their ſecerning Veſſel. And thus we have found out the Uſe of the *Porta*, which; notwithſtanding it makes ſo conſiderable a Figure in the animal Body, yet perhaps no Part was ever leſs minded, or had its Uſe leſs underſtood by the Writers upon the animal Oeconomy.

But that this is moſt certainly the

Uſe of the *Porta* will more evidently appear, if we conſider what Nature ſtill does farther in Proſecution of the ſame Deſign.

The Cavities of all the Arteries increaſe as they divide. The Sum of the Branches, which riſe immediately from the *Aorta*, is to the *Aorta* as 102740 is to 100000: but as if this Proportion was too little to effect the Deſign of Nature, before the Blood arrives at the Liver, the Branches which immediately ſpring from the Trunk of the Meſenterick Artery, increaſe in a much greater Proportion. The Figure of this Artery, as it lies in the middle of the Meſentery, is after this manner.



And in that Body, from which I took the following Proportions, I found 21 Branches to ſpring immediately from its Trunk. In ſuch Parts of which the Trunk of the Meſenterick Artery is 15129

The 1st Branch is	2136
2	1936
3	2136
4	2104
5	4489
6	1936
7	2601
8	3136
9	1681
10	3025
11	625
12	1369
13	1024
14	1849
15	1936
16	529
17	729
18	1156
19	1024
20	1156
21	841
The Sum of all	37418

By theſe Proportions it appears,

that the Sum of the firſt Branches is much more than double to the Trunk of the Meſenterick Artery; and therefore the Velocity of the Blood in them is much leſs than half what it is in the Trunk; whereas in the Branches which come immediately from the *Aorta*, the Diminution of the Velocity is hardly ſenſible. But that I may put this Matter in a clearer Light, I ſhall firſt examine with what Velocity the Blood in the Liver would have moved, if it had been carried there by ſuch Arteries as are every where elſe. Secondly, I ſhall ſhew with what Velocity it would have moved, had it been brought to the Liver by ſuch an Artery as the *Meſenterica Superior*. And Thirdly, I ſhall demonſtrate the Velocity with which it now moves through the Branches of the *Porta* to the Liver.

And firſt let us ſuppoſe that an Artery equal to the Meſenterick (the Square of whoſe Diameter is .038025 Parts of an Inch) had gone directly from the *Aorta* to the Liver, and that the Proportion between its Branches had been the ſame it is every where elſe, to wit, 10000 to 12387. The Logarithm of .038025 is —1.4189307. The Log. of the ſmalleſt Artery has been found to be — 8.6020600, their Difference is —7.1831293, which Number being divided by .2080639 (as has been ſhewn in the ſecond Eſſay) the Quotient 3.4 is the Series of Diviſions of this Artery; and conſequently upon Calculation, the Velocity of the Blood in the laſt Diviſions of the Series, will be found to be to the Velocity in the Trunk of the Artery as 1 to 1448.

But the Velocity of the Blood would have been much leſs if it had been carried by an Artery, ſuch as the Meſenterick, directly to the Liver. I have already ſhewn what Proportion the Trunk of this Artery bears to its firſt Branches; I ſhall now ſet down the Proportion of the ſeveral Trunks to their Branches, that we may find out the general *Ratio*, as we have taught before.

The 5th Branch of the Meſenterick Artery was	4489
Its Branches	1764 2809
	4573
The leaſt of theſe Branches	1764
Divided into four	576 1225 576 1024
	2401
The biggeſt Branch	2809

Divided

Divided into three	961 1764 1521
	4246
One of theſe, to wit,	1521
Divided into two	1369 961
	2330
The 8th Branch of the Meſenterick Artery was	3136
Its Branches	1521 1225
	2746
The biggeſt Branch	1521
Divided into two	900 900
	1800
The leaſt	1225
Divided likewiſe into two	729 900
	1629

The 10th Branch of the Meſenterick Artery was	3025
Its Branches	1936 1600
	3536
The biggeſt Branch	1936
Divided into two	1089 1296
	2385
Of theſe the biggeſt	1296
Divided into two	676 676
	1352
The 14th Branch of the Meſenterick Artery was	1846
Its Branches	900 900 900
	2700

The

The 15th Branch of the Meſenterick Artery was	1936
Its Branches	1089 1369
	2458
Of theſe the biggeſt Branch	1369
Divided into three	784 676 676
	2136
Of which Branch	676
Divided into two	400 529
	929

From all which Numbers, we ſhall take the general *Ratio* of the Trunks to their Branches, to be as the Sum of all the Trunks to the Sum of all the Branches; that is, as 28549 to 36221, or as 10000 to 12687. Now if we calculate upon this *Ratio*, we ſhall find 36 Series of Diviſions in the Meſenterick Artery; and that in the laſt of theſe the Blood moves 5261 times ſlower than it does in the Trunk of the Meſenterick Artery.

As the Trunk of the Meſenterick Artery bears a leſſer Proportion to its Branches, than the *Aorta* does to its Branches; ſo the Branches of the Meſenterick Artery are likewiſe leſs in Proportion to their conjugate Veins, than the *Aorta* is to the *Vena Cava*. The deſcending Trunk of the *Aorta* below the Emulgents is to the *Vena Cava* at the ſame Place, as 324 is to 441: But a Branch of the Meſenterick Artery is to its correſponding Branch of the *Porta*, as 9 to 25: And therefore the Blood in the Branches of the *Porta* moves 14613 times ſlower than it does in the Trunk of the Meſenterick Artery, and that only upon the Account of the Increaſe of the Diameters of the Veſſels. So neceſſary was it to abate the rapid inteſtine Motion of the Blood, which might hinder the Coaleſcence of the Particles for the Formation of the Bile.

Having ſhewn how the Velocity of the Blood decreaſes as it paſſes to the Liver, I ſhall now enquire into the Time it takes in paſſing. If a Blood-veſſel divides into any Number of Branches, of equal Lengths, and the Orifices of the Branches at each Diviſion increaſe in a certain given *Ratio*; the Time the Blood will take to run through ſuch a Veſſel may be thus had. Becauſe the Velocity of the Blood is reciprocally as the Sections of the Veſſels, and the Length the Blood runs being given, the Time is reciprocally as the Velocity; the

Time the Blood moves through each Length will be directly as the Section of the Veſſel; that is, directly as the Sum of the Sections of all the Branches: And therefore, if the Sections are in a Geometrical Progreſſion, the Times will likewiſe be in a Geometrical Progreſſion. Suppoſing then that the Time increaſes at each Diviſion of the Veſſel in the Proportion of 1 to r, the Times will be in this Geometrical Progreſſion, $1.\ r.\ r^2.\ r^3.\ r^4.\ r^5.$ &c. Now if we call the laſt Term of the Progreſſion u, the Sum of the Progreſſion, that is, the Sum of all the Times will be $=\frac{ru-1}{r-1}$: and if we take the Proportion of the Branches of the Meſenterick Artery to be to one another as 10000 to 12687, the Number of Diviſions will be 36, and conſequently ſuppoſing an equal Diſtance between each Diviſion, the

Blood moving with an uniform Motion, will require ſeven and thirty times the Time to run through the whole Length of the Meſenterick Artery, that it does to move from the *Aorta* to the firſt Diviſion of the Meſenterick Artery. In this Proportion r is equal to 1.2687, whoſe Log. is 0.1033589, which multiplied by 36 gives the Logarithm of the Number 5259, which is the laſt Term of the Progreſſion, equal to u, and $r u = r^{37} = 6672$, therefore $r u - 1 = 6671$: Now if from the Log. of 6671 we ſubſtract the Log. of the Number $r - 1$ or of 0.2687, there will remain the Log. of the Number 24826, which is the Sum of all the Times the Blood takes in moving through all the Diviſions of the Meſenterick Artery; and therefore the Time it takes in moving through the Meſenterick Artery, is to the Time it would run along it with ſuch an uniform Motion as it has at the Beginning of the Artery, is as 24826 to 37, or as 670 to 1. Now the Blood in the *Aorta* or Beginning of the Meſenterick Artery, runs at the rate of 78 Feet in a Minute; and therefore if we ſuppoſe the Meſenterick Artery to be 10 Inches long, the Blood would with an uniform Motion run along it in the Space of 0.64 of a ſecond; and conſequently it muſt now take up near 7 Minutes in paſſing through the Meſenterick Artery. But the Velocity in the *Porta* is to the Velocity in the Meſenterick Artery as 9 to 25; and therefore if the *Porta* be ſuppoſed likewiſe to be 10 Inches long, the Blood will be 19 Minutes in paſſing thro' it: So that the Time the Blood takes in paſſing from the *Aorta* to the Liver is at leaſt 26 Minutes; whereas if an

Artery had gone directly from the *Aorta* to the Liver, (according to the uſual Method of Nature) it had paſſed in little more than half a ſecond, that is, in 2437 times leſs Time than it now requires in paſſing. All which does evidently demonſtrate, that the Blood was not in a State to yield Bile, if it had gone directly from the *Aorta* to the Liver; that a much greater Time, and a much more languid Motion, than ſo direct a Paſſage could have allowed, was abſolutely neceſſary to get the bilious Particles in a readineſs to be ſeparated from the reſt of the Blood in the Liver. I have ſuppoſed the Diviſions of the Artery to be all of an equal Length, which indeed they are not, but may, for the eaſier Calculation, without any conſiderable Error, be taken equal one with another.

We have now ſeen how Nature has provided for the Formation of the Bile in the Blood, which paſſes thro' the Meſenterick Artery. We ſhall next conſider what Care is taken of that which is conveighed by the Celiack Artery to the Liver: For it ſeems it was neceſſary to ſend a larger Quantity of Blood to the Liver, than could be diſpoſed of thro' the Inteſtines. Part of the Blood of the Celiack Artery is ſpread upon the Stomach and Caul, and its Velocity diminiſhed, as we have ſeen, in the Inteſtines; but ſtill all the Blood which theſe Parts could receive, was not ſufficient for the Liver, and there was no more room for the diviſion and expatiating of the Veſſels thro' ſuch a large Space as the Meſentery, and a long Tract of Guts. How therefore muſt the Velocity of the reſt of the Blood (to which

The Uſe of the Spleen.

the inteſtine Motion is always proportional) be abated? Nature has here another extraordinary Contrivance, ſhe empties the Blood entirely out of the Veſſels into a large ſpongy Bowel, or rather Ciſtern provided for that intent and purpoſe. I know not the Dimenſions of the Splenick Artery, but the Circumference of the Celiack being ½ an Inch, or .5, its Square is .25; and therefore the Square of the Splenick, which is a Branch of it, cannot be above .18. Now the Dimenſions of the Spleen are 6 Inches in Length, 3 or 4 in Breadth, and 2 in Thickneſs. I ſhall therefore make this eaſy Suppoſition for the more ready Calculation, that it is a Cylinder of 2 Inches Diameter, and therefore the Square of its Circumference being 36, the Blood muſt move 200 times ſlower in the Spleen, than in the beginning of the Splenick Artery: Is not this the long ſought for Uſe of the Spleen? So productive is one ſimple Truth of many others.

From all this Art and Contrivance it is evident Demonſtration, that the Intent of Nature was to diminiſh the Velocity of the Blood, and that ſuch a ſlow Motion was abſolutely neceſſary for the ſecerning of the Bile in the Liver. If the Humours which are ſeparated by the Glands are at all times and places the ſame in the Blood, and not formed after the manner demonſtrated, what need was there for diminiſhing ſo conſiderably the Velocity of the Blood? Let the Blood move faſt or ſlow, they would be always the ſame, and always in an equal aptitude to be ſecerned.

The Proportion of the Bile to the reſt of the Blood.

The Particles which compoſe the Bile, bear a very ſmall Proportion to the reſt of the Blood, as is evident from the great Quantity of Blood that is carried to the Liver, and the ſmall Quantity of Bile that is ſeparated by it. In a large Dog, whoſe *Ductus Cholidochus* was near as big as a Man's, I could never gather above two Drachms in an Hour. Now there is thrown into the *Aorta* every Hour about 4000 Ounces of Blood: And it appears by the Proportions of the Arteries, that the Meſenterick and Celiack are to the reſt, as 1 to 8; and therefore 500 Ounces of Blood are carried every Hour to the Liver. And ſince only two Drachms of Bile are ſeparated from it, the Bile muſt be to the Blood, at leaſt, as one is to two Thouſand. It is by reaſon of this ſmall Proportion of the Bile to the Blood, that it was ſo neceſſary to allow ſo much Time for the Attraction of the Particles which form the Bile. From this Contrivance of the *Porta*, the Bile receives another advantage, not leſs conſiderable than the Diminution of the Velocity of the Blood: And that is the Blood paſſing thro' ſo many different Parts before it comes to the Liver, parts with the greateſt part of its *Lympha*, by which means the Particles, that compoſe the Bile, approaching nearer to one another, are by their mutual Attraction ſooner united. And the conſideration of theſe two Contrivances does highly confirm the truth of this Theory of Secretion: For the Diminution of the Velocity of the Blood, and the Subtraction of the *Lympha*, can agree in no other end than the uniting of the Particles of the Bile.

What has been ſaid concerning the Bile, does ſo evidently prove this Doctrine of Secretions, that there ſeems to be no room to doub of it, even tho' we could not clea the like Difficulty, as to the Formation of the Seed. Yet here agai we meet with another Manifeſtatio of the truth of it, and we find Nature purſuing the ſame Intentio tho' in a different manner, th Structure of the Parts not allowing either of the former Contrivances.

Of the Secretion of the Seed.

The Blood is carried to the Teſticles by the Spermatick Arteries which, contrary to the conſtan Method of Nature in framing th other Arteries, are ſmalleſt wher they ſpring from the Trunk of th great Artery, and immediately dilate to a conſiderable Bigneſs Which evidently ſhews, that ther could be no other Deſign in it, bu to retard the Velocity of the Blood We cannot ſuppoſe that the only Intention was, that a ſmall Quantity of Blood might go to the Teſticles: Becauſe then there had been no Occaſion for giving the Artery a different Figure from all others; that narrow Orifice would have been ſufficient of its ſelf for that purpoſe, which the Wideneſs of the Artery immediately afterwards does neither hinder nor further. The Orifices of the Spermatick Arteries were ſo ſmall, that I could not meaſure them, when I took the Dimenſions of the other Arteries; and yet they are hardly gone from the *Aorta* before they dilate as big, if not bigger than one of the Lumbals, which is 434.2: Now if we ſuppoſe their Orifices to be each 17.3, then the Blood will move 25 times ſlower where the Artery dilates than it does at its Orifice. Again, we conſtantly find that all the Parts of the Body are ſupplied with Blood by ſmall

Arteries from the neareſt Trunks. If this Method had been obſerv'd in ſending the Blood to the Teſticles, they had received their Arteries from the Iliacks; and they had ran but a little way, before they had come to the end of their Journey. But inſtead of this, two ſmall Arteries are made to ariſe from the *Aorta*, a little below the Emulgents, and to march above a Foot before they come to the Teſticles. Now if we conſider that the Velocity of the Blood in the ſpermatick Artery, is 25 times ſlower than it is at its Orifice, that is, in the *Aorta*; and that the Velocity of the Blood in the Iliacks, can be but a very little leſs than it is in the *Aorta*, where the Spermaticks ariſe; the Blood muſt move 25 times ſlower to the Teſticles, than if it had gone after the ordinary manner from the Iliacks: And becauſe the

Space it runs thus ſlowly, is at leaſt ſix times longer than if it had gone from the Iliacks; therefore it muſt be 150 times longer in going to the Teſticles, than if it had gone according to the common Courſe of Nature. So that the inteſtine Motion of the Blood is not only allayed, but ſufficient time is afterwards allowed the Particles, which are to compoſe the Seed, to attract and coaleſce before they arrive at the Teſticles.

Some Objections anſwered.

Perhaps it may be ſaid, that the *Mucus* of the Noſe, and the Wax of the Ear are ſeparated, where the Blood is not ſo languid as their Viſcidity ſeems to require: But I anſwer, that they are Fluids which fall into open Paſſages, where the Air having free Admiſſion, carries off part of their aqueous Fluid; and the Remainder becomes thick, as the *Serum* of the Blood does, when heated. Beſides, we muſt remember, that tho' the Coheſion of the Particles depends upon their Figures; yet the Force by which they attract one another, is likewiſe in Proportion to their Solidities. So that Particles of equal Magnitudes and ſimilar Figures may cohere equally ſtrongly, yet the moſt ſolid will ſooneſt unite. Hence it is, that of two Fluids equally viſcid, the heavieſt may be ſeparated in Glands nearer to the Heart than the other; and that two Fluids of different Viſcidities may be ſeparated at the ſame vicinity to the Heart, if the quantity of the Contacts of the Particles be ſuch as will make amends for their want of Solidity.

Moſt if not all the Secretions contain a greater or leſſer Proportion of the aqueous Fluid, which makes them more or leſs viſcid; yet that which contains the greateſt Quantity, may conſiſt of Particles endued with a very ſmall and ſlow attractive Force: and conſequently ſuch a Fluid cannot be ſeparated by any Gland ſo near the Heart, as that which has a leſs Proportion of the aqueous Fluid, and which conſiſts of Particles endued with a ſtronger attractive Force; and this laſt Fluid may be much more viſcid than the other, whoſe Particles are more diluted by the watry Fluid. Now how it comes to paſs that a greater or leſſer Proportion of the aqueous Fluid is ſeparated in any Gland, I ſhall ſhew in the ſecond Part of this Diſcourſe.

But that the different Viſcidities of the Secretions do not depend only on the greater or leſſer Proportion of the aqueous Fluid, is evident from the foregoing Propoſitions; unleſs any one can ſuppoſe that the Blood conſiſts only of one ſort of Particles: Which Suppoſition, beſides that it contradicts matter of Fact, can never account for the Secretion of ſo many different Fluids. And that the Diverſity of the Attractions in the Particles is the Reaſon, why various Velocities of the Blood, and Diſtances from the Heart, are required for ſecerning of different Liquors, is moſt evident from what has been ſaid concerning the Bile, and the Seed. If only a greater or leſſer Proportion of the aqueous Fluid had been requiſite for ſeparating of different Sorts of Fluids, that might have been done any where, as ſhall be ſhewn afterwards; and Nature had not been put to ſo many Shifts and Contrivances, as we have already ſeen.

Some Fluids may be ſecerned any where.

As ſome Fluids are only to be ſeparated in certain Velocities of the Blood, and at certain Diſtances from the Heart; ſo there may be others that may be ſeparated any where, and in any Velocity of the Blood. Theſe are ſuch as conſiſt of Particles always in an equal Aptitude to be ſecerned; and tho' ſome of them may contain ſeveral ſorts of Particles, yet the Nature of theſe Fluids does not depend upon the Attraction and Coheſion of their Particles. Such a ſort of Secretion is the *Lympha*, which is a watry Fluid ſecerned in all Parts of the Body, for making the Chyle more liquid. If it be ſaid, that ſince the *Lympha* might have been ſeparated any where, and that it ſerves only to dilute the Chyle, that there ought to have been a particular Gland ſomewhere for it in the *Abdomen*, as being the more proper Place: I anſwer, that a large Quantity of *Lympha* was neceſſary for diluting

Why the Lympha *is ſecerned in ſeveral places.*

diluting the Chyle, as appears by the numerous Lympheducts, which diſcharge themſelves into the *Receptaculum Chyli*, *Ductus Thoracicus*, and Subclavian Veins. And if ſuch a Quantity had been ſeparated by a Gland or Glands in the *Abdomen*, appropriated to that Uſe, they muſt have had very large and conſiderable Arteries. The Liver has $\frac{1}{8}$th Part, and the Kidneys near $\frac{1}{8}$th more of the whole Blood, which paſſes thro' the *Aorta*; and if the Lymphatick Glands had had $\frac{1}{8}$th Part more (which is the leaſt they could have had) theſe three Parts would have had near one half of the Blood, and the other half muſt have ſerved all the reſt of the Body: Which would have been a very unequal Diſtribution of the Blood. Beſides, Nature is always very ſimple and frugal in her Operations; ſhe never is at any unneceſſary Trouble: And I will ſhew in the ſecond Part of this Treatiſe how the *Lympha* may be drawn off, by Glands appointed to ſeparate other Fluids; ſo that for this Operation ſhe makes no Part, is at no Expence of Blood: But ſhe muſt have been at a very great one, if ſo much *Lympha* had been drawn off by appropriated Glands.

Of the Secretion of Animal Spirits.

I take the animal Spirits to be another Fluid of this Kind. They undoubtedly conſiſt of by far the ſmalleſt Particles in the Blood, as appears by the Minuteneſs of their ſecerning Glands; and therefore they not being formed by the Coheſion of other Particles, might have been ſeparated any where. Yet the Animal Oeconomy receives a great Advantage by the diſtant Station of the Brain from the Heart; for if it had been placed nearer, and received the Blood, ſtill divided into its ſmalleſt Particles, by the Force of the Air in the Lungs; ſuch Particles might have entred the Glands, as, afterwards cohering to one another, might have obſtructed ſuch extremely narrow Channels. Now the Brain being placed at ſuch a Diſtance, the Particles, that by their attractive Power form Corpuſcles, will have ſufficient time to coaleſce, and their Magnitude will hinder their entring into the Glands. For if it ſhould happen, that theſe Particles ſhould enter the Glands, and there unite together, they would then obſtruct the Paſſage to the Nerves, and produce Apoplexies, Palſies, Coma's, *&c.*

The Particles of which the animal Spirits conſiſt, being of ſuch extreme Fineneſs, their Quantity can bear but a ſmall Proportion to the other Fluids in the Blood; and conſequently there was a Neceſſity of a prodigious Number of Glands to ſeparate them from the Blood; and this is the Reaſon of the great Bulk of the Brain.

Of the Number of different ſorts of Particles in the Blood.

The Operations of Nature are always the moſt eaſie and ſimple. Now how much more eaſie is it to have the ſeveral Secretions formed after the Manner which has been demonſtrated, than to ſuppoſe as many different ſorts of Particles in the Blood, as there are Fluids ſeparated from it? It is not eaſie to determine, how many different ſorts of Particles are in the Blood. Indeed, Phyſick ſeems in nothing ſo defective, as in the Knowledge of the Nature of the Blood. But if the ſame Pains had been beſtowed upon it in a mechanical Way, that have been, in vain, ſpent in ſearch of its Principles by Chymiſts; we had long e'er now had a more perfect Knowledge of its Nature, than ever we can have by Chymiſtry; which can only ſhew how by Art its Parts may be altered, not what Parts it contains.

A few different ſorts of Particles variouſly combined, will produce great Variety of Fluids, ſome may have only one ſort, ſome two, ſome three, or more; and perhaps the aqueous Fluid is the common Baſis of all the Secretions. If we ſuppoſe only five different ſorts of Particles in the Blood, and call them a, b, c, d, e, their ſeveral Combinations, without varying the Proportions, in which they are mixt will be theſe following.

ab: ac: ad: ae:
bc: bd: be: cd:
ce: de: abc: adc:
abd: abe: ace: ade:
bdc: bde: bec: dec:
abcd: abce: acde: abde:
bcde: abcde.

But whether there are more or fewer in the Blood I ſhall not determine.

Of the Operation of Medicines, which alter the Quantity of the Secretions.

No Theory of Secretion has hitherto been able to give any tolerable Account of the Operation of Purgative, Diuretick, or ſuch Medicines as promote any Evacuation. For if the Humours are every where equally mixt with the Blood, that is, if the Blood is in every Part of the Body the ſame, and its Particles are not more apt to form certain Humours, in ſome certain Parts of the Body than in others; or if they are not forced by the Power of any Medicine to form ſuch Humours; then, and in this Caſe, the Quantities of Humour ſeparated in equal times, will be always as the Velocity of the Blood. But the Velocity of the Blood is ſeldom doubled by any Medicine, and never tripled by the moſt acute Fever, as is evident from the Number of Pulſes in a Minute, which I have rarely found above 120 in the higheſt Hectick, and I am apt to think there never were 180 Pulſes in a Minute, which is triple the Number they generally are. The Quantity of Humour, however drawn off by evacuating Medicines, is often 20 times greater than the natural Quantity; and therefore upon ſuppoſition that the Humours are every where equally mixt with the Blood, the Operation of evacuating Medicines can never be accounted for.

Tho' this Argument has the Strength of a Demonſtration, yet there are ſome who explain the Operation of Purgative and other evacuating Medicines by a certain ſtimulating Faculty which they ſay they have, whereby the ſluggiſh Juices are not only forced out, but the obſtructed Channels opened, and the Motion of the Blood is quickned. But tho' we ſhould allow ſuch a Power in theſe Medicines, it would remain to be explained, why certain Medicines do only ſtimulate certain Glands? Why does Jalup affect only the Glands of the Inteſtines, Mercury the ſalival Glands, and Nitre the Kidneys? There certainly can be no Account given of their particular Affection or Antipathy, call it which you will: However let us grant they have ſuch, we ſhall not therefore find them qualified to produce the Effects they do. For firſt it is evident that evacuating Medicines have ſome other Power beſides the ſqueezing out the ſtagnating Juices, becauſe when they are all ſqueezed out, they ſtill evacuate as much, if they are repeated, as they did before; as is plain by continuing a

Salivation for many Days. Secondly, we cannot ſuppoſe that all Bodies have every where, and at all times, Juices ſtagnating, but theſe Medicines conſtantly produce their Effects more or leſs at all times. Thirdly, If we ſhould ſuppoſe half the Veſſels obſtructed, an evacuating Medicine could but double the Quantity that was evacuated before it was taken. Fourthly, If theſe Medicines only operate theſe ways, then in a healthful Body, where there were no Obſtructions, they would have no Effect at all. Fifthly, If the removing Obſtructions were the Cauſe of the greater Quantity evacuated, then the Evacuation ſhould ſtill continue in a greater Degree than before the Obſtruction was removed; whereas in Fact we conſtantly find it leſs as the Medicine works off. Sixthly, Tho' a Medicine by ſtimulating a Veſſel may quicken the Motion of the Fluid in that Veſſel, yet it can never increaſe the Quantity of Fluid running thro' it in equal Spaces of time, becauſe it quickens the Motion of the Fluid only by contracting the Veſſel; and therefore the faſter the Fluid is made to run hrough the Veſſel, the leſs Fluid he Orifice of the Veſſel admits; nd conſequently after the Veſſel is contracted by the ſtimulating Medicine, the Secretion will be leſs inſtead of being greater. That a *Stimulus* cauſes the Part upon which t acts to contract, is matter of Fact; nd that Purgative Medicines do ſtimulate the Bowels, every ones own Experience convinces him: But perhaps it may be ſaid that they likewiſe ſtimulate the Heart, and increaſe its Force; being they not only quicken, but raiſe the Pulſe; ſo that a greater Quantity of Blood

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is ſent to the Glands of the Guts: This I readily grant, but deny that this is the principal Action of Purgative Medicines; becauſe that by the ſame Force a greater Quantity of Blood is ſent to all the other Glands of the Body, whoſe Fluids are not however ſenſibly increaſed; and the Glands of the Inteſtines, receive a leſs Quantity in Proportion than any others, becauſe they cannot be ſo much dilated by the greater Force of the Blood, as others, which are not ſo much ſtimulated by the Medicine.

There are others who will have evacuating Medicines endued with an attenuating Quality, by which they diſſolve all the Coheſions of the Particles of the Blood, and ſo ſet the ſeveral Humours at Liberty to paſs through their proper Glands. But if theſe Medicines have a Power to diſſolve univerſally all the Coheſions of the Blood, then every evacuating Medicine would equally and indifferently increaſe the Quantity of every Secretion; Mercury would as conſtantly purge as ſalivate, and Nitre promote Perſpiration as well as Urine; but this is repugnant to Experience. If they have a Power to diſſolve certain Coheſions, and not others, what is this but the ſetting certain Particles of the Blood at Liberty to paſs through their proper Glands, which were not ſo before? And is not this a preparing the Humours in the Blood, in order to increaſe the Quantity of Secretion? Muſt not therefore evacuating Medicines have a Power to affect and operate upon ſome Particles and not others, that is, to repel ſome Particles, attract retain and alter others? And this is what we affirm to be in all Medicines,

cines, and what a thouſand chymical Experiments evince.

There has never yet been any Theory of Secretion which would from one Principle explain the different Operations of evacuating Medicines. The Operation of Purgative Medicines has been generally explained by their ſtimulating Faculty, of Diureticks by liquifying the Blood, and Sudorificks by heating and rarifying it. Whereas Nature always acts the moſt ſimply; and from this one ſimple Principle of different Medicines attracting different Particles of the Blood, the Operation of all evacuating Medicines is moſt eaſily accounted for.

The ſeveral Humours being formed by the different Coheſions of the Particles of the Blood, the Quantity of Humour ſecerned by any Gland, muſt be in a Proportion compounded of the Proportion, that the Number of the Particles, cohering in ſuch a manner as is proper to conſtitute the Humour which paſſes through the Gland, bears to the Maſs of Blood, and of the Proportion of the Quantity of Blood that arrives at the Gland. And hence it follows, that where there is a determined Quantity of a certain Humour to be ſeparated, the Number of the Particles that are proper to compoſe the ſecerned Liquor, muſt be reciprocally proportional to the Quantity of Blood that arriveth at the Gland: And therefore if the Quantity of the Secretion is to be increaſed, the Number of the Particles is to be increaſed; if the Secretion is to be leſſened, the Number of the Particles, that are proper for ſuch a Secretion, is to be leſſened in the ſame Proportion. Medicines therefore which can alter the Coheſions and Combinations of the Particles, can either increaſe or diminiſh the Quantity of any Secretion. Thus for example, ſuppoſe the Humour which paſſeth through the Glands of the Inteſtines to be compoſed of three or four ſeveral ſorts of Particles; that Medicine which will eaſily cohere to theſe Particles, and cohering increaſe their mutual Attractions, ſo as they unite in greater Numbers at, or before they arrive at the Inteſtines, than they would have done if the Medicine had not been given, muſt neceſſarily increaſe the Quantity of Humour, which paſſeth through the Glands of the Inteſtines, if the Quantity of Blood which arrives at the Glands is not diminiſhed in the ſame Proportion, as the Number of the Particles is increaſed. After the ſame manner do Diureticks, Sudorificks, and Medicines which promote all other Secretions, operate.

Specifick Purges.

If Medicines, which increaſe the Quantity of any Secretion, operate by uniting to, and augmenting the attractive Force of the Particles, which compoſe the Humours to be ſecerned; may not the Particles of ſome Humours, ſooner, more eaſily, and ſtrongly unite to the Particles of ſome ſort of Medicines, than to another ſort? And conſequently, may not different Humours require different purgative Medicines to carry them off thro' the Glands of the Inteſtines? And does not this re-eſtabliſh the Doctrine of elective Purges, confirmed to the Ancients by Experience and Obſervation, but rejected by the Moderns thro' a falſe Philoſophy?

Why the increaſing the Quantity of ſome Secretions ſhould diminiſh that of others, it is not eaſy to explain by any other Theory. For if the Blood is equally mixt in every Part of the Body with all the Humours which are ſeparated from it, that is, if the Mixture of the Blood is every where alike; ſo that every Humour bears the ſame Proportion to the reſt of the arterial Blood, in one Part of the Body, that it does in another, (as all other Theories ſuppoſe) and if every Humour has its own proper Gland thro' which it is ſeparated; then, what is ſeparated by one Gland, is not ſubtracted from another, and conſequently does not diminiſh the Quantity of Humour which flows to this other, but indeed does rather increaſe the Quantity of this other Secretion; for the more any one Humour is carried off, the greater Proportion any other remaining in the Blood, bears to the remaining Blood: And therefore the more any one Secretion is increaſed, the more all the reſt ſhould be encreaſed likewiſe. But if all the Humours are compoſed by the Combination of a few different ſorts of Particles, then the more apt theſe Particles are to run into any one ſort of Combination, the leſs all other Combinations muſt be; and conſequently the increaſing of any one Secretion, muſt neceſſarily diminiſh the Quantity of all others, but moſt eſpecially of that which has the moſt of the ſame ſort of Particles.

If the ſeveral Humours which are ſeparated from the Blood, are not formed after the manner we have ſhewn, then the Blood muſt be compoſed of near thirty ſimple Humours, for ſo many at leaſt are conſtantly ſeparated from it. But to ſuppoſe the Blood compoſed of ſo many ſimple Humours, as are daily ſecerned in the Glands, is not at all agreeable to that Simplicity which Nature affects in all her Operations. The Principles of all natural Bodies, are ſaid by Philoſophers not to exceed the number five; and yet how prodigious is the Variety, which reſults from their different Mixtures, and Modifications. A few Rays of Light, of different Refrangibilities, mixt all together, produce a white Colour; but variouſly combined exhibit all imaginable Variety of Colours. And can we imagine Nature to have made uſe of leſs Art and Contrivance, in the building of a Fabrick, whoſe every Part demonſtrates the Wiſdom of the Builder, and excites our Wonder and Admiration. No, undoubtedly the ſeveral Humours are compoſed by the various Combinations, and Mixtures, of a few different ſorts of Particles: This is agreeable to the Methods of Nature, which never uſes more Means, or Inſtruments, when fewer will do: It is evident that in many of the Humours ſhe actually uſes this Method; and this Method ſuppoſed, gives a more eaſy and ſatisfactory Account of the ſeveral *Phænomena* of Secretion, than has ever yet been given by any other Theory. For if the ſeveral Humours are formed by the various Combinations of a few Particles, what can give a more eaſy and natural Account of evacuating Medicines, than to ſuppoſe them to have a Power of drawing certain Particles of the Blood to one another, in order to form a Humour, which being therefore more abundant in the Blood, muſt neceſſarily be ſeparated in a greater Quantity? And this is no hard, nor unnatural Suppoſition, when chymical Experiments evince that there is ſuch a Power in every Particle of matter. If therefore Medicines have ſuch a Power, and the Humours are compoſed as has been ſaid, it is Demonſtration that evacuating Medicines do operate in the manner has been explained, and that all other Accounts which are contrary to this are falſe and groundleſs.

How it comes to paſs that the Blood in every Individual is more apt to fall into ſome certain Combinations, than it is in others, I freely own my Ignorance ; but from this Propenſity ariſes all the different Temperaments and Conſtitutions of the humane Body. For it is not the more copious Secretion of any of the more noted Humours, which conſtitutes a Temperament ; but it is a certain Proportion of all the Humours amongſt themſelves, and perhaps to every Proportion there is an agreeable Fitneſs and Diſpoſition of the ſolid Parts. The common Nature of Animals allows of as many different Temperaments, as there are kinds of living Creatures; and every Individual of each Kind, may as well have its own proper Temperament, as its peculiar Features and Lineaments. Some Temperaments may differ ſo little from one another, that the leaſt change may make them fall into one another. Others again are ſo widely different, that the whole Force of Nature can never drive the one into the other. And ſeeing the Combinations of the Humours are almoſt infinite, ſome muſt be very ſingular, and very different from the generality of Combinations; and from thence it is that we find very odd, and remarkable Conſtitutions, in which not only Medicines, but even Meats and Drinks have not their uſual, but many times a quite contrary Effect. And upon this depends the different Appearances of the ſame Diſtemper in different Perſons; and for the ſame Reaſon it is, that what proved ſucceſsful to one, will not always in the like Caſe relieve another.

Nature has not confined the Health of humane Bodies to one certain and particular Conſtitution, to which the nearer any other is, the more healthful it is; and the farther from it, the leſs: But as in a Clock, it is not at all neceſſary to its going well, that the Movements be diſpoſed after one certain manner, or that they be joined together in one certain Proportion; but there may be ſeveral Diſpoſitions, and Proportions, all equally good: So there are ſeveral Temperaments, or Conſtitutions, which neceſſarily produce good Health. As every Kind of Animals, tho' of very different Temperaments from one another, may enjoy a perfect Health; ſo undoubtedly this Health may be equally diſtributed to ſeveral Temperaments of each Kind. There are many perfectly beautiful Diſpoſitions of the different Features of the Face, there are many more which cannot be ſaid to be diſagreeable, but the Multitude of ugly ones is almoſt infinite. It is the ſame thing with the Humours of the Body; a perfect Health may be the reſult of various Proportions of the Humours amongſt themſelves; the ſeveral Degrees of Health may ariſe from a much greater Variety in the Proportion of the Humours; and without doubt there may be innumerable Combinations inconſiſtent with any Degree of Health.

The Knowledge of Secretion neceſſary for the underſtanding the Nature of Diſeaſes

The Animal Body is nothing but a Machine, whoſe Actions and Motions are all performed by Fluids ſecerned from the Blood, and Secretion is the Spring of all the animal Functions. By its means the Heart beats, the Blood circulates, the Limbs are moved, and the Aliments concocted and digeſted, and in a word, the whole Animal Oeconomy, and Life depend upon it; the Blood its ſelf ſeeming to have little other uſe, beſides the recruiting and renewing the ſecerned Liquors. I ſay therefore, ſince Life and Health depend upon the Secretions; ſo likewiſe muſt all Diſeaſes, which are ſaid to be univerſally in the Blood, and many of thoſe which affect particular Parts. If the Quantity and Quality of all the Secretions are ſuch as are proper and uſeful for the ſeveral Purpoſes, for which by Nature they are intended, how is it poſſible but that the whole Animal Oeconomy, muſt be in right Order, and that Body in a good State of Health? Unleſs we can ſuppoſe an Error in the firſt Contrivance of the Body; a Suppoſition no Man in his Senſes can make. But if the Quantity of any Secretion exceeds its due Bounds, what Diſorders it makes is evident from a Diarrhæa, Diabetes, Epiphora, Sweatings, *&c.* If the Quantity of any Secretion falls ſhort of what it ought to be, the Effects are of no leſs pernicious Conſequence; as appears from a Suppreſſion of Urine in the Kidneys, from the Jaundice and a Stoppage of Perſpiration. And that the Quality of the Secretions altered do likewiſe create great Diſorders, is obvious from the Pains of the Cholick, of a Diarrhæa, and Dyſentery, from the Sharpneſs of Urine, which ſometimes produces

Ulcers in the Bladder and Kidneys; and even the Spittle is known to corrode the Mouth. I have choſen to give moſt Inſtances of ſuch Secretions, as are properly Evacuations, becauſe their Effects are apparent to every Body, and cannot poſſibly be ſaid to be only a Notion. But if the Alteration of thoſe is of ſuch ill Conſequence, what Effects muſt an undue Quantity, or the vitiated Quality of theſe, which are retained in the Body, and employed about the neceſſary Functions of Life, produce? The Diſorders they create, are not ſo evidently the Effects of their ill State, tho' by a juſt reaſoning, we may ſometimes deduce them; and therefore a right Notion of Secretion muſt be of the greateſt Uſe and Importance, for the underſtanding of moſt Diſeaſes.

Of a Diabetes.

I ſhall only inſtance in a Diabetes, and from this Doctrine of Secretion explain the Nature of that Diſeaſe hitherto unknown. The Symptoms which precede a Diabetes, are little wandring Pains, and frequent Twitchings of the Tendons; theſe are followed by a profuſe Evacuation of a clammy, ſweetiſh Urine, as if Honey were diſſolved in it; which is conſtantly attended with a Thirſt, quick Pulſe, Faintneſs, and Loſs of Strength: All which depend upon the Flux of Urine, and increaſe and diminiſh in the ſame Proportion with it. The evident Cauſe of this Diſtemper is an habitual drinking of ſtrong Liquors, and the more ſpirituous they are, the ſooner and more violently they bring it. But a Diabetes is not always cauſed by an habitual drinking of ſtrong Liquors, for ſometimes it proceeds from ſome internal and latent Cauſe. However, the Nature of the Diſeaſe is always beſt known, by conſidering what Effects the evident Cauſes of it produce in the Body.

By an habitual drinking of ſtrong Liquors, it comes to paſs in proceſs of Time, that the *Serum*, or thin Part of the Blood, contains a large Proportion of a ſpirituous Fluid; or that Part of the *Serum* which ſhould be Water, is for the greateſt part Spirit. Now the Salts of the Urine or Blood, will not diſſolve in a vinous Spirit, that is, the Particles, of which the Salts conſiſt, are more ſtrongly attracted by one another, than they are by ſuch a Fluid, as by Experiments it appears. And therefore the Quantity of Salts in the Blood, will be daily increaſed, and circulating thro' the capillary Veſſels, muſt irritate the fine Fibres, and cauſe little Pains and Twitchings all over the Body. But when the *Serum* is full of theſe Salts, the diſtance between them and the Globules of the Blood will be leſs; and conſequently they will attract the Globules of the Blood more ſtrongly than the Globules attract one another; and the Globules, or red Part of the Blood, will be diſſolved and diffuſed thro' the *Serum* of the Blood. And this again is confirmed by Experiments; for nothing does render the red Part of the Blood ſo fluid, and keep it more from coagulating, when drawn in a Cup, than urinous Salts and Spirits. When the red Part of the Blood is thus diſſolved and united to its *Serum*, it will with the *Serum* be carried off thro' the Glands of the Kidneys, and being united to the Salts, will alter their Figures and Properties; as Litharge and

Corall do the Salts of Vinegar, giving them a ſweet Taſte.

All quick Evacuations of the Veſſels muſt diminiſh the Quantity of Fluid ſeparated in the Glands; and therefore the greater Quantity of Urine is voided in a ſmall time, the leſs *Saliva* and animal Spirits will be ſecerned by their reſpective Glands: And conſequently Thirſt, Faintneſs, and Loſs of Strength will increaſe, as the Quantity of Urine excreted increaſeth.

This being the State of the Blood, it is evident that the Indications of Cure, are to diſſolve the Coheſions of the Salts with the Blood, and to carry them off by Urine. Theſe can be anſwered by nothing ſooner or better than Waters, which are therefore to be drunk in large Quantities. And of all Waters, thoſe which have a Tincture of Lime are beſt, becauſe Lime does ſtrongly attract urinous Salts.

I could ſhew the Uſefulneſs of this Doctrine, in explaining ſome Symptoms of Fevers, Rheumatiſms, Small-Pox, and ſome other Diſeaſes, which are not thought to depend upon Secretion; and from thence deduce what things are hurtful, and what uſeful in the ſeveral Methods of curing them: But that would carry me beyond my preſent Deſign, and perhaps may more fuller be illuſtrated ſome time hereafter. I will only take notice, that from this Theory, we have a plain and eaſie Account of the Thickneſs of the Blood in Rheumatiſms; for it is known, that this Diſeaſe ariſing generally from a Cold, the frigorifick Particles entering the Pores of the Skin, not only diſpoſe the Blood to run into ſuch Coheſions

Of Rheumatiſms.

ſions as are proper to form the Humours ſecerned in the Glands of the Lungs or Noſe; but they alſo give a ſtrong Attraction and Coheſion to the Particles ſwimming in the *Serum* of the Blood, which will be ſtrongeſt in the Extremities where the Motion of all the Particles is near equal by the 11th Propoſition. That it is in this manner our Blood is affected in Colds, and not by the Stoppage of the Pores, as is generally thought, I could very evidently prove. This equal Celerity of the Particles of the Blood in the Extremities, is likewiſe the Reaſon why the Concretions of the Gout are formed there; unleſs by frequent Debauches, or a Decay of Nature, the Motion of the Blood becomes ſo languid, that theſe Particles eaſily attract one another in the Blood-veſſels of the Bowels, where I have ſhewn that the Motion of the Blood is

Of the Gout.

is alſo very ſlow: And then ſuch Remedies as warm and increaſe the inteſtine Motion of the Blood, and thereby diſturb the Attraction of the gouty Particles, relieve the Bowels, and ſend the peccant matter to the Extremities again. To this Attraction of the Particles in the Urine, is owing the Formation of Gravel and Stone in the Kidneys and Bladder; and the Nucleus of the Stone in the Bladder, being almoſt equally ſurrounded every where with the Fluid of Urine, its Attractions are almoſt every where equal; and therefore the Stone is made up of ſo many parallel Shells or *Laminæ*. Now from this it demonſtratively follows, that copious and liberal drinking muſt neceſſarily prevent the Growth of both: For by that the attractive Particles are removed at a diſtance too great to attract one another. Provided always

Of the Stone.

always that the Drink be ſuch, as is not highly ſaturated with Particles, which eaſily and ſtrongly attract one another; what theſe Drinks are, they who know the Nature of the Liquors which are commonly drunk will eaſily underſtand.

The Operations of Medicines explicable by Attraction.

As this Principle of Attraction will account for moſt Diſeaſes; ſo I doubt not, but that by it likewiſe the Operations of all ſorts of Medicines may be explained. For example, Medicines which thicken the Blood, are ſuch as conſiſt of very ſmall Particles, and endowed with a ſtrong attractive Force, by which eaſily cohering to the Globules of the Blood, they increaſe their Attraction to one another, and ſo produce a Coagulation, or at leaſt a thickening of the Blood. On the contrary, if a Medicine conſiſts of ſuch Corpuſcles, as will eaſily unite with the aqueous Particles,

cles, and increaſe their Attraction; ſo that they attract the Globules of the Blood with a greater Force than theſe Globules attract one another, then will the Globules recede from one another, be diffuſed thro' the *Serum*, and the *Coagulum* be diſſolved. A *Gonorrhea* is undoubtedly produced by a very active Salt, which being ſtrongly attracted by the Humour in the Glands, and uniting to it, like the Acids of Salt and Vitriol to Mercury in the Preparation of Sublimate, forms a very virulent *pus*, which corrodes the Veſſels, and produces Ulcers. And as Sublimate loſes its corroſive Faculty by the Addition of more Mercury, which ſtrongly attracts its acid Salts; ſo Mercury mixt with the Blood, attracts the acid Salts of the Pox, and uniting to them, carries them off, either by Stool, Spittle, or otherwiſe. This Power, by which

The Operation of Mercury.

which Mercury attracts acid and ſharp Salts, is the Reaſon why Cinnabar is ſo good a Medicine in fixt and vagrant Pains, as in a Rheumatiſm: For the Urine of Rheumatick Perſons is found upon Examination, not to contain its due Quantity of Salts, which therefore being retained in the Blood turn acid, and produce Pains.

Now who can doubt of the Truth of a Principle ſo ſimple, and yet which like a Maſter-key opens Works of very different Contrivances, and diſcloſes an Uniformity in all the Operations of Nature; ſo that every one may ſee and read the ſame Thought and Hand in the Contrivance and framing of every part of the Univerſe. By it we ſee the Reaſon why the Branches of all the Arteries in the Body, have the Sum of all their tranſverſe Sections greater than the tranſverſe Section of the *Aorta*; for if it had been otherwiſe, there could have been no Mucilage ſeparated for the eaſy Motion of the Joints, without ſuch a Structure as the Spleen at every Joint where this Mucilage was neceſſary. By it the Reaſon not only of the general Structure of the Veſſels is demonſtrated, but likewiſe the Neceſſity of the Frame and Situation of the particular Parts, as of the Lungs, Spleen, *Porta*, and of all the Glands. By it the Nature of the Blood and all the Secretions may be explained. By it the whole animal Oeconomy, and all its Diſorders, the ſeveral Diſeaſes incident to the Body, the Nature of their Remedies, and the ways of their Operations may be accounted for. This is that grand Principle, by which all the Particles of matter in this Planet are actuated. By which, but with a different Force, all the Planets are carried round the Sun; and as the projectile Velocity of the Planets, adjuſted to the Sun's Attraction, cauſes them to move in their ſeveral Orbits; ſo the Velocity of the Blood, adapted to the Attraction of its Particles, cauſes the ſeveral Humours to be ſecerned at certain diſtances from the Heart by their reſpective Glands.

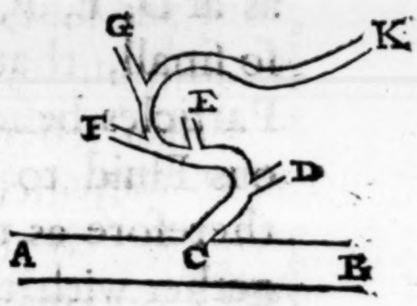
I ſhall now proceed to the ſecond thing I propoſed to ſhew; which is, *The manner whereby the ſeveral Fluids, after they are formed in the Blood, are ſeparated from it by the Glands.*

This does depend intirely upon the Figure and Structure of the Glands; which muſt be therefore firſt determined. As Truth when plain and evident does of it ſelf diſpel all falſe Opinions; ſo the true Structure of the Glands being once demonſtrated, there will be no Occaſion to refute the Doctrine of Ferments; nor the Hypotheſis of Tubes differing as to the Figures of their Orifices, both which have been ſeveral times demonſtrated to be falſe.

That the Glands are nothing but Convolutions of ſmall Arteries, the greateſt and moſt accurate Anatomiſts of this Age, *Malpighius*, *Bellini* and *Nuck* have diſcovered. And indeed that all the Veſſels of the Body, in which the Liquors are continually moving, can have no other than a Cylindrical or Conical Form, is demonſtrable from the Nature of Fluids, whoſe Preſſure is always perpendicular to the Sides of the containing Veſſel, and equal at equal Heights of the Fluid: If therefore the ſides of the Veſſels are ſoft, and equally yielding every where (ſuch as are all the Tubes in the Body of a *Fœtus*) they muſt by the Preſſure of their contained Fluid, be equally every where diſtended; and conſequently the Section of ſuch a Veſſel perpendicular to its Axis muſt be a Circle, and therefore the Veſſel muſt be either a concave Cone or Cylinder, or at leaſt ſuch a Figure whoſe tranſverſe Section is a Circle.

The Circular Orifices therefore of the Glands can only differ in Magnitude, and all ſorts of Particles of a leſſer Diameter than that of the Orifice of the Gland may enter it; ſo that without ſome farther Contrivance, that Fluid which contains the biggeſt Particles, muſt likewiſe conſiſt of all the Particles of all the other Secretions; neither could any Fluid thicker than the Blood be ſeparated from it, becauſe of the great Proportion of the aqueous Fluid; whoſe Particles being vaſtly ſmaller than any other, and inviſible to the beſt Microſcopes, muſt enter all the Glands, and be mixt with the ſecerned Fluid.

How this Inconveniency may be prevented, and how the Particles of any ſize may either be ſeparated by themſelves, or with any aſſigned Proportion of the aqueous Fluid, or of other leſſer Particles, I ſhall now endeavour to ſhew.



Suppoſe A B to be a ſmall evaneſcent Artery, and that the Particles of the leaſt ſize were to be ſeparated from the reſt. From the ſide of the Artery muſt ariſe the Gland or Tube CK, whoſe Orifice at C is ſuch as is capable of admitting only Particles of the leaſt ſize, together with the aqueous Fluid; theſe therefore will be ſeparated from all the other Particles of the Blood, and the Tube C K being a

Cylinder, they will paſs to its farther end K, which is ſuppoſed to be the excretory Duct of the Gland.

If the Quantity of the aqueous Fluid, ſeparated with the leaſt Particles muſt be diminiſhed, that ſuch a Fluid as is requiſite may paſs thro' the excretory Duct K, from the Tube C K, you muſt imagine that ſeveral other ſmaller Canals go out, as at D, E, F, G, whoſe Orifices are ſo ſmall, that they admit no other Particles beſides thoſe of the aqueous Fluid to paſs thro' them; and therefore as the leaſt Particles, together with the aqueous Fluid paſs along the Tube C K, the aqueous Fluid muſt conſtantly be diminiſhed, the Quantity of the leaſt Particles ſtill remaining, the ſame can paſs no where, but thro' the excretory Duct K; and this Diminution of the aqueous Fluid will be always according to the Number of the Canals D, E, F, G, that is, in Proportion to the Length of the Tube CK; and therefore according as the Gland is longer or ſhorter, ſo the more or leſs aqueous Fluid will paſs thro' the Orifice of the excretory Duct K, and conſequently the ſecreted Fluid upon this account be thicker or thinner.

If the Particles of a middle ſize, between the biggeſt and the leaſt, are to be drawn off from the reſt of the Blood; let the Orifice at the Gland C be juſt ſo big as to admit theſe Particles, and not any of thoſe that are bigger: Theſe Particles therefore, together with the aqueous Fluid, and all leſſer Particles will paſs thro' the Orifice C: But if the Canals D, E, F, G, are big enough to receive all the other Particles, and too narrow to admit the Particles that are to be ſeparated; it is evident, that thoſe

Particles muſt arrive at the excretory Duct K, with what Proportion of leſſer Particles is required.

Thus we ſee how any ſort of Particles may be drawn off, either by themſelves or mixt with any others in any Proportion, and this is done in the moſt ſimple manner, only by Arteries; for C K is only a ſmaller Artery, ſtraight, ſpiral, or otherwiſe contorted; and D, E, F, G, are again Arteries ſmaller than it; and if any of theſe are ſo ſmall, as to admit only Particles of *Serum*, they conſtitute Lymphatick Veſſels; from thence it is that we find *Lympheducts* to ariſe in great Numbers from thoſe Glands that ſeparate thick Humours, as from the Teſticles, Liver, *&c.*

ESSAY

ESSAY V.

OF

Muſcular Motion.

A Muſcle is a Bundle of thin and parallel Plates of fleſhy Threads or Fibres, encloſed by one common Membrane: All the Fibres of the ſame Plate are parallel to one another, and tied together at extremely little Diſtances, by ſhort and tranverſe Fibres. The fleſhly Fibres are compoſed of other ſmaller Fibres encloſed likewiſe by a common Membrane: Each leſſer Fibre conſiſts of very ſmall *Veſicles* or Bladders into which we ſuppoſe the Nerves, Veins and Arteries to open; for every Muſcle receives Branches of all thoſe *Veſſels*, which muſt be diſtributed to every Fibre. The two Ends of each Muſcle, or the Extremities of the Fibres, are in the Limbs of Animals faſtened to two *Bones*, the one moveable, the other fixt; and therefore when the Muſcles contract, they draw the moveable *Bone* according to the Direction of their Fibres. When the Muſcles contract in Length, they ſwell in Thickneſs, as may be perceived by laying the Hand upon the *Maſſeter*, a Muſcle of the lower Jaw, and preſſing the Grinders together: But this Power of contracting or ſwelling is loſt when either the Artery or Nerve of the Muſcle is cut or tied; and therefore we conclude that the Contraction, Swelling, or Motion of the Muſcles is performed by the *Blood* and *Animal Spirits* diſtending the *Veſicles* or Cavities of the Fibres. This Diſtention of the *Veſicles* of the Fibres muſt be either by their being filled with a greater Quantity of *Blood* and animal Spirits than they were before the Contraction, or the *Blood* and Spirits mixing muſt rarifie, and fill up a greater Space.

That the *Veſicles* of the Fibres are not diſtended purely by the Quantity of *Blood* and Spirits, will appear if we conſider, that were the *Veſicles* diſtended only by the Quantity of Fluids contained in them, Nature (whoſe Operations are always the moſt ſimple) had only uſed one Fluid and not two; for in the Works of Nature we no where find two neceſſary Cauſes where one could have produced the ſame Effect: Now how ſmall ſoever we ſuppoſe the Quantity of Fluid brought by the Nerves to the Muſcles, that alone might have contracted the Fibres (if a Quantity only of a Fluid had been requiſite) by diminiſhing the Diameters of the Cavities or *Veſicles* of the Fibres, as will appear by the ſequel of this Diſcourſe. And as it is evident that the Reaſon why the Spirits alone do not diſtend the *Veſicles*, is not that there is not a ſufficient Quantity for that purpoſe; ſo it will likewiſe appear that if there had not been a ſufficient Quantity of the nervous Fluid, yet the Quantity of Blood could have given no Aſſiſtance in the Diſtention of the *Veſicles*; for if the *Veſicles* contain a greater Quantity of *Blood* when the Muſcles contract, than they do when the Muſcles are relaxed, this Augmentation muſt proceed either from the *Blood's* being ſtop'd in the *Vein*,

Vein, or it muſt move ſuddenly with a greater *Velocity* thro' the Artery into the Cavities of the Fibres. If the *Blood* is ſtopp'd in the *Vein*, it muſt be by the Contraction of its Coats, or by ſome external Preſſure upon them: If by the Contraction of the Fibres which compoſe the Coats of the *Vein*, the ſame Difficulty remains to be explained; for whatever is the cauſe of the Contraction of the Fibres of a *Vein*, will likewiſe ſerve to contract the Fibres of a *Muſcle*. If the *Blood* is ſtopp'd in the *Veins* by a Preſſure upon their Coats, it muſt be by the ſwelling of the Artery or muſcular Fibres. If the Artery ſwells and preſſes on the *Vein*, the Circulation of the *Blood* muſt be intirely ſtopp'd; for that Preſſure will conſtantly increaſe, the *Blood* being ſtill accumulated in the Artery; and therefore it will for ever hinder all Paſſage through the *Vein:* If it be ſaid that the *Blood* moving ſometimes with a greater *Velocity* through the Artery into the Cells or *Veſicles* of the Fibres, will diſtend them; this greater *Velocity* muſt proceed from the Force of the Heart, from which alone the *Blood* derives all its Motion: Now if the Heart acts with a greater Force, it will increaſe the *Velocity* of the *Blood* univerſally throughout the whole *Body*, and each Muſcle and its Antagoniſt will be thereby equally contracted, and conſequently neither will contract. And therefore being both the *Blood* and Fluid of the Nerves are neceſſary to the Contraction of the Muſcles, and being the Contraction is not performed by the Quantity of theſe Fluids, it remains only that by their Mixture, they rarifie and diſtend *Veſicles.*

Now for the explaining of this Rarifaction of the *Blood* and Spirits in the *Veſicles* of the muſcular Fibres, let us ſuppoſe a ſmall Globule of Air between the Particles of a Fluid, and that the Particles have a ſtrong attractive Force by which they endeavour to come together, they preſſing every way equally on the Globule of the Air, will hinder it from eſcaping any way from between them; but the Force by which they endeavour to come together, being prodigiouſly greater than the Force of their Gravity, they will by this Force produce a very conſiderable Condenſation of the Globule of Air that lies between them; and the Force of Elaſticity being proportional always to its Condenſation, the Force by which this airy Globule will endeavour to expand its ſelf, will likewiſe be vaſtly great; and conſequently if by any means this *Niſus* of the Particles of the Fluid to come together ſhould be taken off, the Air between them would expand its ſelf with a very conſiderable Force. Now if upon the mixing of another Fluid the Particles of the firſt Fluid ſhould be more ſtrongly attracted to the Particles of this other Fluid, than they were before to one another; then would their *Niſus* to one another ceaſe, and they would give the Globule of Air that is between them Liberty immediately to expand it ſelf, and the whole Fluid would take up a greater Space than it did before. But when the Particles of the two Fluids come to be united together, they will again encloſe the Globule of Air that lies between them, and by their mutual Attraction ſoon bring it to its former State of Condenſation.

Now that the *Blood* contains a great Number of Globules of Air is evident from the Quantity it yields in the Air Pump. And that the Particles of the *Blood* have a ſtrong attractive Force is likewiſe plain from what has been ſaid in the Theory of Secretion. By this Attraction of the Particles, the Globules of the *Blood* are formed; and in viewing the Circulation of the *Blood* with a Microſcope, I have ſometimes obſerved, that where the Diameter of the Canal has been leſs than the Diameter of a Globule of *Blood*, that the Globule would be preſſed into a Spheroidical Form, but when it came into a wider Part of the Canal again, it would immediately re-aſſume its former Figure; which I think is probably owing to a ſmaller Globule of Air encloſed within, and expanding its ſelf equally every way, when the Sides of its circumambient Shell of *Blood*, are not longer preſſed by the Sides of the Canal.

Theſe Globules of *Blood* continually circulating through the *Veſicles* of the Fibres (which are probably capable of containing only one Globule at a time) meet with the animal Spirits, which drop from the Nerves. Now the Minuteneſs of the *Glands* of the Brain, and the Smallneſs of the Fibres of the *Nerves*, plainly ſhew that the *animal Spirits* are a Fluid, conſiſting of the ſmalleſt Particles of any in the Body; and therefore their attractive Force muſt be the greateſt of all the Particles in the Blood, as is evident from what Sir *I. Newton* has calculated about the Rays of Light; and conſequently the *animal Spirits* meeting with the *Globules* of the Blood in the *Veſicles* of the Fibres, and ſurrounding them, muſt attract the Particles of which they are compoſed, more ſtrongly than they do another; and conſequently their *Niſus* to one another ceaſing, the condenſed Globule of Air will expand its ſelf with a very conſiderable Force, whereby each *Veſicle* of the Fibre will be diſtended, and conſequently the Fibre ſhortned, *i. e.* the whole Muſcle will be contracted. But when the Particles of the Globule of *Blood* are mixed with the nervous Fluid, they will both together encloſe the Globule of Air again, and compreſs it into as ſmall a Space as it was before; and thus the Contraction of the Muſcle muſt immediately ceaſe, unleſs freſh Blood and Spirits ſtill ſucceeding one another continue the Inflation of the *Veſicles*. But when a Muſcle has been ſtrongly contracted for ſome time, the Quantity of Spirits ſpent, being more than can be ſecerned in the ſame ſpace of Time by the Glands which ſupply its Nerves, the Inflation of the *Veſicles* muſt fall, and the Muſcle grow feeble and weak; whereas the Tonick Motion of the Muſcles, being performed by the Spirits protruded only by the Quantity laſt ſecerned in the Glands, will conſtantly continue without any Wearineſs.

After this manner I conceive the *Veſicles* to be diſtended without any Ebullition or Efferveſcence, and their Diſtention to ceaſe without any Precipitation, or flying off of the aerial Globules through the Pores of the Muſcles. For to this Attraction of the Particles of Matter is owing moſt of the *Phænomena*; for explaining of which Philoſophers have been forced to have recourſe to active and ſubtile Particles, which contrary to their own

Principles they have made to move themſelves every way, and to do whatever they had a mind ſhould be done: But how theſe Particles came by ſo great an Activity was not at all to be accounted for from any of their Principles. Thus in explaining of Muſcular Motion they make the animal Spirits to cut and pierce the Globules of Blood, and with their ſharp Points to run them through and through, that the impriſon'd elaſtick *Aura* might be ſet at Liberty; which notwithſtanding could not be effected, unleſs we ſuppoſe that Holes may be made in fluid Globules, as in a Board, and that the fluid Particles ſtand in a Heap, as the Waters of the red Sea did. And when the Aerial Globule is got looſe, the Intumeſcence of the *Veſicle* cannot be aſſwaged, but by ſuppoſing the elaſtick Globules now to have Strength to break through the Muſcles and Skin to come at the external Air, tho' before they had not Power nor Subtilty enough to get through a thin Shell of Blood.

But I come now to ſhew the Mechaniſm of the Fibres, or how excellently and wiſely they are contrived for Contraction: It is a known Experiment that a Bladder when it is blown up and diſtended as to its Capacity, but contracted as to its Length, will by the Force of Contraction, raiſe a Weight to ſome determined height. And if two Bladders joined together and communicating with one another were blown up, the Weight would be raiſed by Inflation twice the Space that one alone would do it; becauſe I ſuppoſe that both Bladders contract equally, and conſequently the Contraction of both together will be double the Contraction of either. Three Bladders thus joined and diſtended will raiſe the Weight to triple the Height, and four to quadruple; ſo that if there were a String of Bladders join'd together, of equal Bulk and like Figures, the ſpace through which the Weight wou'd riſe, wou'd be proportional to the Number of Bladders, or, which is the ſame thing, to the Length of the String.

Each Fibre of a Muſcle conſiſting of a Multitude of ſmall *Veſicles*, reſembles a String of Bladders; and therefore the Contraction of the Muſcle, is always proportional to the Length of its Fibres. And being the greateſt Contraction of the Fibres is always leſs than $\frac{1}{3}$ of their Length (as ſhall hereafter be demonſtrated) there was a Neceſſity that the Inſertions of the Muſcles ſhould be near to the Joints, not only to increaſe the Velocity of the Parts moved; but likewiſe that they might deſcribe greater Arches round the Centers of their Motion: And hence it is that thoſe Parts which deſcribe the greateſt Arches, are moved by the longeſt Muſcles; as the Hand round the Elbow, which is bent by the *Biceps* ariſing from the *Scapula*; and the Foot round the Knee, which is bent by the Muſcles whoſe Originations are as far diſtant as the *Iſchium*. If theſe Joints had been moved by ſhort Muſcles inſerted at each end into the Extremities of the articulated Bones, the Arm and Leg had moved but a little way, and the Arches the Hand and Foot had deſcribed about theſe Joints, had been to the Arches they deſcribe now, as the Length of the ſhort Muſcles had been to the Length of the Muſcles they have now. On the contrary, where the Joints have but a ſmall Motion there the Muſcles are ſhort: Thus we find that the Fingers are pulled ſide-ways by the *Interoſſæi*, the Thigh is drawn outwards, and obliquely by the *Quadragemini* and *Obturatores*, which are all ſhort Muſcles, and moſt of the Muſcles of the *Vertebræ* run between one *Vertebra* and the next. From hence it is evident that the Originations and Inſertions of the Muſcles, are every where the beſt that could be contrived.

The Veſicles of which the Fibres conſiſt are extremely ſmall; for tho' one large Bladder may raiſe a Weight as high as ſeveral ſmall ones, yet the Quantity of Elaſtick Fluid uſed in the Inflation, together with the ſwelling of the large Bladder, will be much greater than when a Weight is raiſed by a String of ſmall ones. For ſuppoſe two Bladders of ſimilar Figures, but the Diameter of the one triple to the Diameter of the other, then will the one require twenty ſeven times the Quantity of Elaſtick Fluid to expand it that the other does, and it will ſwell to twenty ſeven times the Space; and yet three of the leſſer Bladders joined together, will raiſe the Weight to the ſame Height that the bigger one does, but with nine times leſs Expence of Elaſtick Fluid, and they will take up but one ninth Part of the Space. By diminiſhing therefore the Bigneſs of the Veſicles, and increaſing their Number, the Force required to diſtend the Veſicles, and the Diſtention its ſelf, may be diminiſhed in any given Proportion, and come at laſt to be inſenſible. Suppoſe a Bladder of a determined Bigneſs can raiſe a Weight a Foot; a hundred Bladders whoſe Diameters are each $\frac{1}{100}$

part of the former being blown up, will raiſe the Weight to the ſame Height, but the Force of Inflation and the ſwelling of all put together will be ten thouſand times leſs than in the large one.

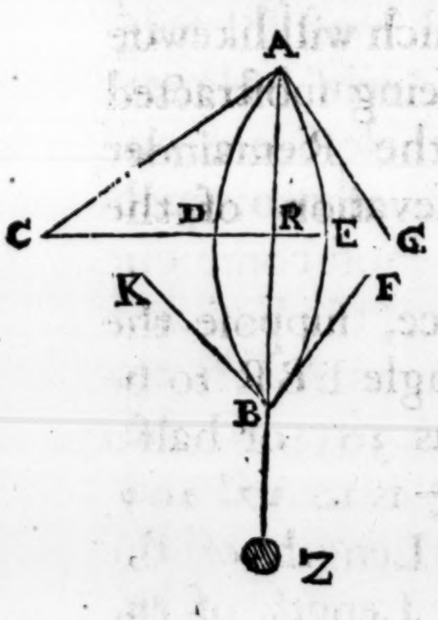
If a Weight of a determined Bigneſs can be raiſed to a certain Height by one Bladder, or one String of Bladders to which the Weight is tyed; twice that Weight may be raiſed by two ſuch Bladders, or Strings of Bladders, and triple that Weight by three ſuch Strings. And conſequently the Weight a Muſcle can raiſe, will be always as the Number of its Fibres, that is, as its Thickneſs, ſuppoſing the Diſtention of the Veſicles equal. And the abſolute Strength of one Muſcle is to the abſolute Strength of another, as their Bulks.

It is to be obſerved that in determining both the Contraction and

Strength of a Muſcle, no Regard is to be had to the Tendons; becauſe in them we obſerve no Inflation, and we find Nature no where making uſe of a Tendon, but where either there was not room for the Inſertion of ſo many fleſhy Fibres, or where it was neceſſary the Muſcle ſhould draw from ſuch a Point.

I ſhall in the next Place determine the Force of the Elaſtick Fluid neceſſary to diſtend the Veſicles ſo as to raiſe to a determined Height any given Weight. But before this can be done, the Figure that each Veſicle will be formed into by the Force of the Elaſtick Fluid diſtending it, muſt be found out: And therefore let us conceive each Veſicle to conſiſt of an infinite Number of Threads, whoſe Ends are faſtened by tranſverſe Ligaments; and from hence it follows that if a diſtended Veſicle were cut with a Plane thro its Axis, the Curve of the Section will be the ſame with that of a Thread whoſe two Ends are faſtened, and the whole preſſed by an Elaſtick Fluid; and becauſe Elaſtick Fluids endeavour to expand themſelves every way, and all Fluid preſs perpendicularly on each Obſtacle, it is evident that the Thread muſt be every where equally and perpendicularly preſſed, and therefore its Flexion or Curvature muſt be every where equal and ſimilar, and conſequently the Thread muſt be formed into a circular Arch. Hence it follows that the whole Secretion of the Veſicle conſiſts of two equal and ſimilar Arches, whoſe common Subtenſe is the Axis of the Veſicle. Suppoſe now A E B and A D B to be the two circular Arches, C the Center of the Arch A E B, A G and B F Tangents in the Points A and B, Z the Reſiſtance to be raiſed. The

Angle C A G or C A E is equal to a right Angle = to C A R + A C R, and therefore the Angle A C R = G A R, or E A R = E B R = D B R; and therefore the Arch E A or E B is the Meaſure of the Angle E A R, or E B R, and the Space through which the Reſiſtance Z is raiſed is equal to the difference between the Arch A E B and its Chord A R B, or equal to twice the difference of the Arch A E and its Sine A R; which having the Arch A E or the Angle E A R given in Degrees and Minutes may be eaſily calculated. But to do this the Length of the Radius A C muſt be determined in ſuch Parts, whereof 100000 make up the Arch AE, which is done thus. The Degrees



Degrees of a circular Arch, whoſe Length is equal to the Radius of the Circle is 57° 295; and therefote the Degrees in the Arch A E is to 57° 295, the Length of the Radius expreſſed in Degrees, as 100000, the Parts of which the Arch AE conſiſts, to the Radius expreſſed in the ſame Parts, which will therefore be given. And again, as the Tabular Radius is to the Tabular Sine of the Arch AE, ſo is the Radius A C (which is already found) to the Sine A R, which will likewiſe be found. This being ſubſtracted from A E and the Remainder doubled, is the Elevation of the Weight Z.

Thus for Inſtance, ſuppoſe the Arch AE or the Angle EBR to be 30 Minutes, ſay, as 30′, or half a Degree, that is $\frac{5}{10}$ is to 57° 295, ſo is 100000 the Length of the Arch AE, to the Length of the

Radius AC which will be found to be 11459000. And again, as 100000 is to 872 the Sine of 30′, ſo is 11459000 to AR, which is therefore 99906, which ſubſtracted from AE, and the Remainder doubled, gives 186 the Sublevation of the Weight Z in ſuch Parts whereof AE is 100000.

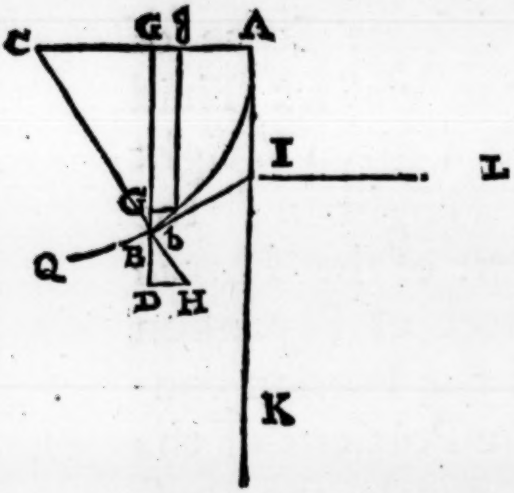
The Tenſion of the Fibre or the Force wherewith it is ſtretch'd by the Reſiſtance Z may be thus determined. The Tenſion of the Fibre, or the Force ſuſtaining the Weight in the Point B, is the ſame as if the Weight Z were ſuſpended by two Threads touching the Arches in the Point B, and in that Caſe the Tenſion of the Thread BF is to the Weight Z, as the Sine of the Angle FBR or EBR is to the Sine of the Angle FBH or EBD; *(a)* and conſequently the Tenſion or Firmneſs of the Thread will be $= \frac{Z \times \text{Sine } EBR}{\text{Sine } EBD}$

(a) *By the 2d cor. prop.* 33 *of the* Lectiones Phyſicæ Jo. Keil.

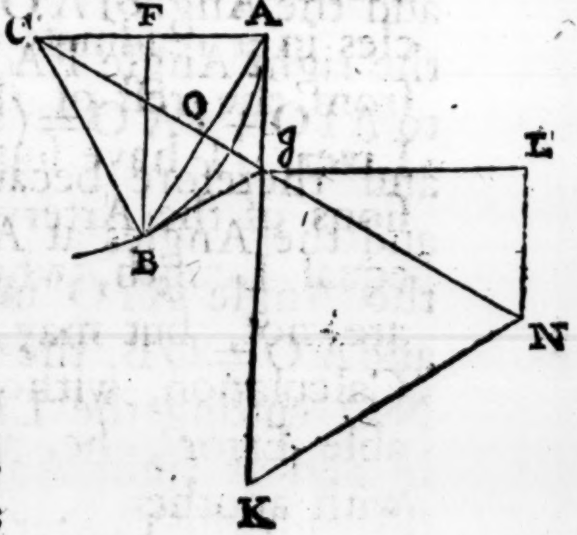
Now call the abſolute Force of Expanſion that the elaſtick Fluid muſt have to raiſe a given Weight to a determin'd Height *n*; the Preſſure on any Part of the Thread will be as the Force of Expanſion of the Fluid, and the Portion conjunctly; for if the Portions of the Thread be taken equal, the Preſſures on them will be as the Force of Expanſion, or the Elaſticity; and if the Force of Expanſion be the ſame, the Preſſure is as the Portions on which it preſſes; and therefore univerſally it is as the Force of Expanſion and the Portion jointly, or as the Product of the two.

Let AB repreſent the circular Thread, B b an indefinite ſmall Portion of the ſame, and the Preſſure on B b will be $n \times Bb$, which ſuppoſe equal to BH: The

Preſſure BH can be reſolved into two Forces, one whereof is as DH



acting horizontally, or according to the Direction DH, and the other at BD acting vertically, or according to the vertical Direction BD; and becauſe of the equiangular Triangles GBb and BDH. BG : DH : : Bb : BH : : Bb : $n \times$ Bb (: : 1 : n) : : Gb : BD; therefore DH $= n$ BG, and BD $= n$ Gb, and therefore the Sum of all the horizontal Forces will be equal to n multiplied by all the BG's, that is n multiplied by BF $= n \times$ BF, and the Sum of all the vertical Forces is equal to n multiplied by all the Gb's, that is $= n$ AF. Now it is plain that the Tenſion of the Fibre in the Points A and B is the ſame with the Tenſion of two Threads Tangents in the Points A and B (where they are ſuppoſed to be faſtened) that are drawn at their Point of Concourſe I, by all the horizontal Forces according to the Direction I L, and by all the vertical Forces according to the Direction I K: And therefore to determine the Tenſion of the Fibre, the Tenſion muſt be determined of the Threads that are pulled at the Point I by a Force *n* F B according to the Direction I L, and by a Force *n* F A according to the Direction I K. Take I L = *n* F B and L N perpendicular to it = *n* F A, and the two Forces



I L and L N will be equipollent to a third Force as I N, acting according to the Direction I N, and therefore the Threads will be ſtretch'd to the ſame Degree by the Force I N that they would be by the two Forces I L and L N, and becauſe I L (n B F) : L N (n F A) : : B F : F A, and the Angles at L and F equal (by the 6th of the 6th) the Triangles B F A and I L N will be equiangular, and the Side I N will be equal to n B A, and the Angle F A B = L N I = (by 29. 1.) A I O, add the Angle I A O to both, and the right Angle F A I will be equal to A I O + I A O = (32. 1.) A O C; and therefore becauſe A I = I B, and the Angles at A and B equal, the Angle A I O muſt be = B I O and A O = O B, the Line therefore N O cutting the Line A B equally and at right Angles muſt paſs through the Center. Through N draw N K parallel to B I, meeting with A I produced in the Point K, then the Forces by which the Threads are ſtretched will be as I K and N K, * the Angle K I N = A I O = F A B = B I O = I N K. The Triangle therefore K I N is an Iſoſceles Triangle, and equiangular to the Triangle A B C, and A B : A C : : N I : I K : : *n* A B : *n* A C; and therefore I K or K N will be equal to *n* × A C, that is the Forces by which the Threads are ſtretch'd will be equal to the Radius of the Circle multiplied by *n*.

Hence the Tenſion of the Fibre in the Points A and B, and ſo in all other of its Parts, is the ſame and equal to the abſolute Force of Elaſticity multiplied into the Radius of the Circle. But the Tenſion of the Fibre was found before to be $\frac{Z \times \text{Sine } EBR}{\text{Sine } EBD}$, therefore if we call the Radius r. $nr = \frac{Z \times \text{Sine } EBR}{\text{Sine } EBD}$ and $n = \frac{Z \times \text{Sine } EBR}{r \times \text{Sine } EBD}$ and $r \times$ Sine E B D will have the ſame Proportion to the Sine E B R as Z to n. Hence it is plain that no finite Force of Elaſticity can extend the Fibre A E B D to a complete Circle, for in that caſe the Sine of the Angle E B D being nothing $r \times$ Sine E B D is nothing, and therefore Z will be to n as nothing to ſomething, or as a finite to an infinite.

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* Keil's Lectiones Phyſicæ, *prop*. 33.

The greateſt Contraction of the Fibre that can be, muſt always be leſs than 72728 of ſuch Parts whereof the Arch AE is 100000, for if the Threads were extended into complete Circles, the Contraction would be only $\frac{72728}{100000}$ of A E, which it can never arrive to; therefore the Contraction muſt be always leſs than $\frac{1}{3}$ of the Length of the Fibre:

bre: It is alſo plain that when the Angle EBR is ſmall, the Force of Elaſticity bears but a ſmall Proportion to the Reſiſtance. For Example when the Angle EBR is but 30′ the Radius or r multiplied into the Sine of the Angle EBD the Sine of one Degree, is to the Sine of the Angle EBR the Sine of 30′ as Z to n, that is, $r \times 1745 : 872 :: Z : n$, that is $Z : n :: 11459000 \times 1745 : 872 :: 19995955000 : 872 :: 22931141 : 1$, and conſequently a ſmall Degree of Elaſticity will produce a prodigious Energy in the Muſcles.

FINIS.

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